DSMS Telecommunications Link
Design Handbook

301, Rev. B
Coverage and Geometry

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Change Log

Rev	Issue Date	Affected Paragraphs	Change Summary
Initial	11/30/2000	All	New Module
A	4/15/2003	2.1.1, 2.1.4, 2.2.3, 3.	Identified 11-m subnet as non-operational. Corrected equations 4, and 7. Added DSS 55. Documented improved coverage for MDSCC antennas. Expressed Geodetic coordinates in terms of WGS84 ellipsoid. Revised Proposed Capabilities.
B	2/5/2004	2.1.2, 2.1.2.1, 2.11.2.2, 2.1.5, 2.2.3.6, 2.2.3.10, 2.2.4	Corrects locations of DSS 26, 54 and DSS 55. Revises locations of other stations. Adds Table 7 (location uncertainties). Provides final receive and transmit masks for DSS 55. Adds Figure 8 and renumbers subsequent figures.

Note to Readers

There are two sets of document histories in the 810-005 document that are reflected in the header at the top of the page. First, the overall document is periodically released as a revision when major changes affect a majority of the modules. For example, this document is part of Revision E. Second, the individual modules also change, starting as the initial issue that has no revision letter. When a module is changed, a change letter is appended to the module number on the second line of the header and a summary of the changes is entered in the module's change log.

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1 Introduction

1.1 Purpose

This module describes the geometry and surveillance visibility provided by the DSN for support of spacecraft telecommunications.

1.2 Scope

This module provides the Deep Space Network (DSN) station coordinates that are required for spacecraft navigation and to locate the stations with respect to other points on the Earth's surface. Coverage charts are provided to illustrate areas of coverage and non-coverage from selected combinations of stations for spacecraft at selected altitudes. Horizon masks are included so the effects of terrain masking can be anticipated.

2 General Information

2.1 Station Locations

The following paragraphs discuss the important concepts relating to establishing the location of the DSN antennas.

2.1.1 Antenna Reference Point

The coordinates provided by this module refer to a specific point on each antenna. For antennas where the axes intersect, the reference point is the intersection of the axes. For antennas for which the axes do not intersect, the reference point is the intersection of the primary (lower) axis with a plane, perpendicular to the primary axis, and containing the secondary (upper) axis. Table 1 lists the DSN antennas by type and provides the axis offset where appropriate. The effect of this offset is to cause the range observable to be a function of antenna position as discussed in module 203 of this handbook.

Although the antenna reference point is fixed, the path length between this point and a spacecraft increases as the antenna elevation is changed from zenith to the horizon. This results from the antenna subreflector being moved to provide maximum gain as gravity distorts the antenna geometry. The effect can be modeled as a decrease in antenna height for orbit determination purposes. The effect is greatest on the 70-m antennas and is discussed in the appropriate Telecommunications Interface modules of this handbook.

Table 1. DSN Antenna Types

Antenna Type	Station Identifiers	Primary and Secondary Axes	Axis Offset
70-m	14, 43, 63	Az/El	0
34-m High Efficiency (HEF)	15, 45, 65	Az/El	0
34-m Beam Waveguide (BWG)	24, 25, 26, 34, 54, 55	Az/El	0
34-m High-speed Beam Waveguide (HSB)	27, 28†	Az/El	1.83 m
26-m	16, 46, 66	X/Y	6.706 m
11-m OVLBI	23, 33, 53†	Tilt/Az/El	0.391 m

Az/El Antenna's azimuth plane is tangent to the Earth's surface, and antenna at 90-degrees elevation is pointing at zenith.

X/Y Primary axis (X) is aligned horizontally in an east-west direction. Secondary axis is aligned in a vertical, north-south plane.

Tilt/Az/El The azimuth axis of the Az/El mount is tilted to avoid an overhead keyhole. The direction of tilt is fixed for each pass and results in an apparent shift in the actual station location from the specified station location.

† DSSs 23, 28, 33, and 53 are not presently in service.

The 11-m antennas are unique in that the azimuth axis is tilted from the local vertical by a 7-degree wedge that is rotated to a position with respect to north called the "train angle" before the start of each track. This causes the station location to be displaced away from the train angle along a circular path having a radius equal to the axis offset. The vector ($\Delta\mathbf{r}_b$), which must be added to the station coordinates to compensate for this effect, can be derived from the train angle that is supplied to the user as part of the tracking data (see module 302) and the north and east station vectors (**N** and **E**) which are functions of the station geodetic coordinates.

$$\Delta\mathbf{r}_b = -0.391\cos\alpha\,\mathbf{N} - 0.391\sin\alpha\,\mathbf{E} \qquad (1)$$

where:

$\square$ = the train angle

$$\mathbf{N} = \begin{bmatrix} \square\sin\square_g \cos\square \\ \square\sin\square_g \sin\square \\ \cos\square_g \end{bmatrix} \tag{2}$$

$$\mathbf{E} = \begin{bmatrix} \square\sin\square \\ \square\cos\square \\ 0 \end{bmatrix} \tag{3}$$

$\square_g$ = Station Geodetic Latitude (Table 5)

$\square$ = Station Longitude

2.1.2 IERS Terrestrial Reference Frame

To use station locations with sub-meter accuracy, it is necessary to clearly define a coordinate system that is global is scope as opposed to the regional coordinate systems referenced in previous editions of this document. The International Earth Rotation Service (IERS) has been correlating station locations from many different services and has established a coordinate frame known as the IERS Terrestrial Reference Frame (ITRF). The IERS also maintains a celestial coordinate system and coordinates delivery of Earth-orientation measurements that describe the motion of station locations in inertial space. The DSN has adopted the IERS terrestrial system to permit its users to have station locations consistent with widely available Earth-orientation information.

The IERS issues a new list of nominal station locations each year, and these locations are accurate at the few-cm level. At this level of accuracy, one must account for ongoing tectonic plate motion (continental drift), as well as other forms of crustal motion. For this reason ITRF position coordinates are considered valid for a specified epoch date, and one must apply appropriate velocities to estimate position coordinates for any other date. Relative to the ITRF, even points located on the stable part of the North American plate move continuously at a rate of about 2.5 cm/yr.

The coordinates in this module are based on the 1993 realization of the ITRF, namely ITRF93, documented in IERS Technical Note 18 [(1)]. ITRF93 was different from earlier realizations of the ITRF in that it was defined to be consistent with the Earth Orientation Parameters (EOP) distributed through January 1, 1997. Earlier realizations of the ITRF were known to be inconsistent (at the 1-3 cm level) with the Earth orientation distributions.

After ITRF93 was published, the IERS decided to improve the accuracy of the EOP series and make it consistent with the ITRF effective January 1, 1997. This date was chosen because it enabled a defect in the definition of universal time to be removed at a time when its contribution was zero. In anticipation of this change, ITRF94 and ITRF95 were made consistent with the pre-ITRF93 definition of the terrestrial reference frame, and all prior EOP series were recomputed in accordance with the new system.

The DSN continues to deliver Earth-orientation calibrations to navigation teams that are consistent with the earlier definition and using the ITRF93 reference frame because it is impractical for planetary navigators to adopt an IERS standard that changes approximately every year. Users interested in precise comparison with other systems should keep in mind the small systematic differences.

2.1.2.1 Cartesian Coordinates

Figure 1 illustrates the relationship between the Cartesian coordinates and geocentric coordinates discussed below. The Cartesian coordinates of the DSN station locations are fits to many years of tracking and Very-Long Baseline Interferometry data and are expressed in the ITRF93 reference system in Table 2.

2.1.2.2 Estimated DSN Site Velocities

The locations given in Table 2 are for the epoch 2003.0. To transform these locations to any other epoch, the site velocities should be used. Table 3 gives the site velocities for the DSN stations, in both Cartesian (x, y, z) and east-north-vertical (e, n, v) components.

2.1.3 Geodetic Coordinates

Locations on the Earth’s surface are defined with respect to the geoid. That is, the surface around or within the Earth that is normal to the direction of gravity at all points and coincides with mean sea level (MSL) in the oceans. The geoid is not a regular surface because of variations in the Earth's gravitational force. To avoid having to make computations with respect to this non-mathematical surface, computations are made with respect to an ellipsoid, that is, the surface created by rotating an ellipse around one of its two axes. The ellipsoid is uniquely defined by specifying the equatorial radius and the flattening (that is, the amount that the ellipsoid deviates from a perfect sphere). The relationship between the polar and equatorial axes is given by the following expression:

$$\text{(polar axis)} = \text{(equatorial axis)} \times (1 - 1/\text{flattening}) \tag{4}$$

In the past, the ellipsoid used was chosen to be a best fit to the geoid in the area of interest. However, the presence of the Global Positioning Satellite (GPS) system has resulted in a single ellipsoid, named the WGS 84 Ellipsoid, being adopted for most geodetic measurements. This ellipsoid, while providing a good fit to the entire Earth, results in larger differences between the geoid and the ellipsoid than could be obtained when ellipsoids were chosen to fit only a

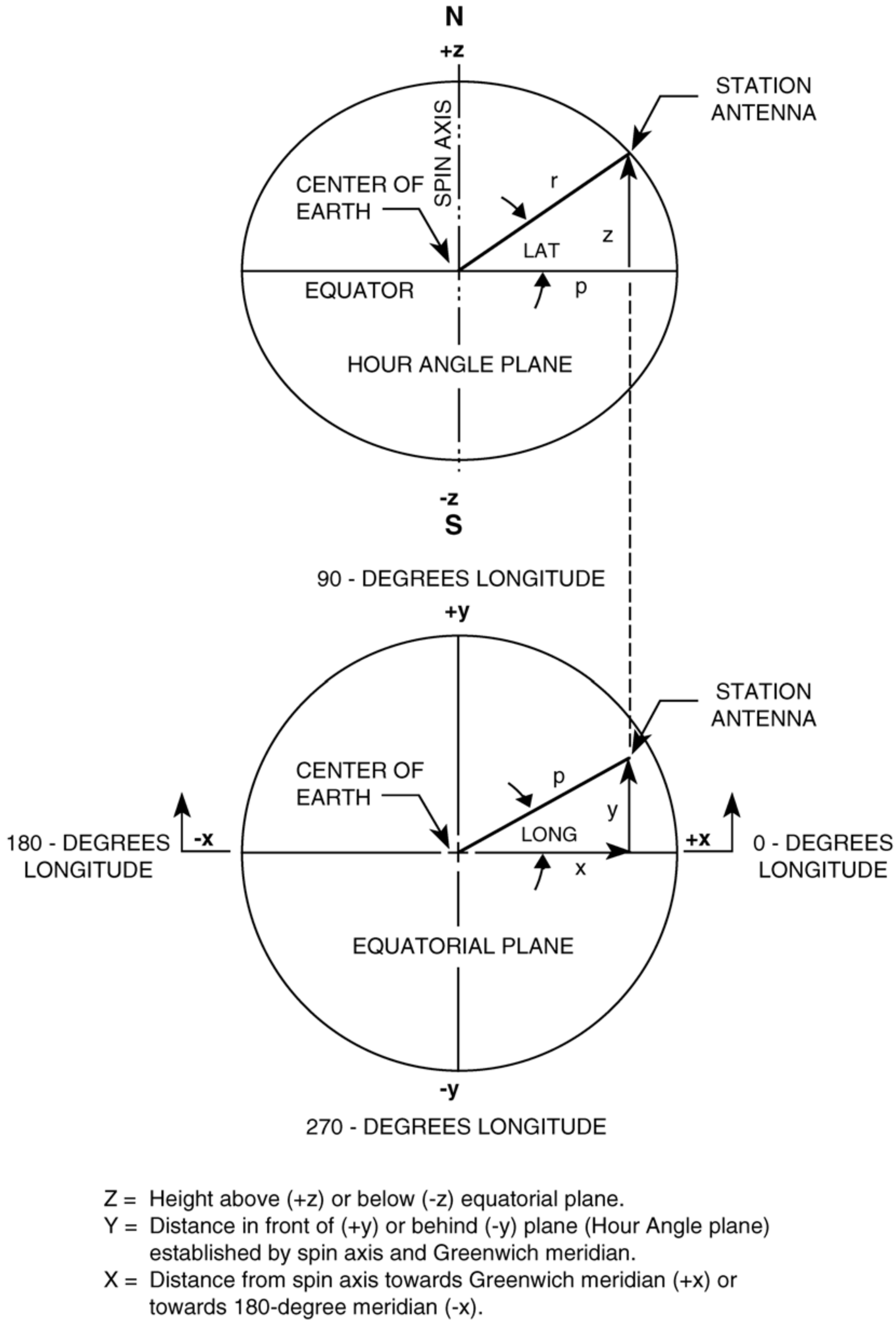

Figure 1. Cartesian and Geocentric Coordinate System Relationships

Table 2. Cartesian Coordinates for DSN Stations in ITRF93 Reference Frame, Epoch 2003.0

Antenna[1]		Cartesian Coordinates		
Name	**Description**	**x(m)**	**y(m)**	**z(m)**
DSS 13	34-m R & D	–2351112.6586	–4655530.6359	+3660912.7276
DSS 14	70-m	–2353621.4197	–4641341.4717	+3677052.3178
DSS 15	34-m HEF	–2353538.9575	–4641649.4287	+3676669.9837
DSS 16	26-m X-Y	–2354763.3257	–4646787.3837	+3669387.0099
DSS 23[2]	11-m Tilt/Az/El	–2354757.7341	–4646934.5965	+3669207.7651
DSS 24	34-m BWG	–2354906.7087	–4646840.0834	+3669242.3207
DSS 25	34-m BWG	–2355022.0140	–4646953.2040	+3669040.5666
DSS 26	34-m BWG	–2354890.7996	–4647166.3182	+3668871.7546
DSS 27	34-m HSB	–2349915.4275	–4656756.4059	+3660096.4693
DSS 28[2]	34-m HSB	–2350102.0169	–4656673.3686	+3660103.5180
DSS 33[2]	11- m Tilt/Az/El	–4461083.8425	+2682281.6961	–3674569.9725
DSS 34	34-m BWG	–4461147.0925	+2682439.2385	–3674393.1332
DSS 43	70-m	–4460894.9170	+2682361.5070	–3674748.1517
DSS 45	34-m HEF	–4460935.5783	+2682765.6611	–3674380.9824
DSS 46	26-m X-Y	–4460828.9473	+2682129.5071	–3674975.0884
DSS 53[2]	11-m Tilt/Az/El	+4849330.0161	–0360337.8678	+4114758.9123
DSS 54	34-m BWG	+4849434.4877	–0360723.8999	+4114618.8354
DSS 55	34-m BWG	+4849525.2561	–0360606.0932	+4114495.0843
DSS 63	70-m	+4849092.5175	–0360180.3480	+4115109.2506
DSS 65	34-m HEF	+4849336.6176	–0360488.6349	+4114748.9218
DSS 66	26-m X-Y	+4849148.4311	–0360474.6175	+4114995.1679

Notes:

1. All antennas are AZ-EL type unless otherwise specified.
2. DSSs 23, 28, 33, and 53 are not presently in service.

Table 3. Site Velocities for DSN Stations

Complex	x(m/yr)	y(m/yr)	z(m/yr)	e(m/yr)	n(m/yr)	v(m/yr)
Goldstone (Stations 1x & 2x)	−0.0180	0.0065	−0.0038	−0.0190	−0.0045	−0.0003
Canberra (Stations 3x & 4x)	−0.0335	−0.0041	0.0392	0.0208	0.0474	–0.0012
Madrid (Stations 5x & 6x)	−0.0100	0.0242	0.0156	0.0234	0.0195	0.0012

portion of the Earth. This difference, the *Geoidal Separation*, must be subtracted from the WGS 84 height measurements to give the height with respect to mean sea level.

Geoidal separations are typically determined from satellite altimetry and gravity measurements and maintained as a grid of points in longitude and latitude. Modern GPS equipment uses a sixteen point interpolation routine to estimate the surface curvature in the grid-square of interest and the geoidal separation at the specific point within the grid-square. Table 4 provides the average geoidal separation for the three DSN complexes. These numbers do not take into consideration such things as topography within the complex and grading that was done when the antennas were installed.

Table 4. Average Geoidal Separations for the DSN Complexes

Complex	Geoidal Separation(m)
Goldstone (Stations 1x & 2x)	−30.6
Canberra (Stations 3x & 4x)	19.3
Madrid (Stations 5x & 6x)	54.1

Once the Cartesian coordinates (x, y, z) are known, they can be transformed to geodetic coordinates in longitude, latitude, and height (λ, ϕ, h) with respect to the ellipsoid by the following non-iterative method (Reference 2):

$$\lambda = \tan^{-1}\frac{y}{x} \tag{5}$$

$$\phi = \tan^{-1}\left[\frac{z(1-\mathrm{f}) + e^2\mathrm{a}\sin^3\mu}{(1-\mathrm{f})\left(p - e^2\mathrm{a}\cos^3\mu\right)}\right] \tag{6}$$

$$h = p\cos\phi + z\sin\phi - a\left(1 - e^2\sin^2\phi\right)^{\frac{1}{2}} \tag{7}$$

where:

$$\mathrm{f} = \frac{1}{\text{flattening}} \tag{8}$$

$$e^2 = 2\mathrm{f} - \mathrm{f}^2 \tag{9}$$

$$p = \left(x^2 + y^2\right)^{\frac{1}{2}} \tag{10}$$

$$r = \left(p^2 + z^2\right)^{\frac{1}{2}} \tag{11}$$

$$\mu = \tan^{-1}\frac{z}{p}\left[(1-\mathrm{f}) + \frac{e^2\mathrm{a}}{r}\right] \tag{12}$$

Table 5 provides geodetic coordinates derived by the preceding approach using the WGS84 ellipsoid that has a semi-major axis (a) of 6378137 m and a flattening of 298.2572236.

2.1.4 Geocentric Coordinates

Geocentric coordinates are used by navigation analysts when corrections to station locations are being investigated. They relate the station location to the Earth's center of mass in terms of the geocentric radius and the angles between the station and the equatorial and hour angle planes. Geocentric coordinates for the DSN stations are provided in Table 6.

2.1.5 Station Location Uncertainties

The primary reference antennas at each complex are the 34-m HEF antennas. Their location has been established by very-long baseline Interferometry (VLBI) measurements over a period of many years and their location uncertainty is that of the VLBI technique. The uncertainty of the other station locations depends on the method used to link their position to that of the HEFs. The estimated location uncertainties for all stations are provided in Table 7.

Table 5. Geodetic Coordinates for DSN Stations With Respect to the WGS 84 Ellipsoid

Antenna[1]		latitude (ϕ)			longitude (λ)			height(h)[3]
Name	**Description**	**deg**	**min**	**sec**	**deg**	**min**	**sec**	**(m)**
DSS 13	34-m R & D	35	14	49.79131	243	12	19.94761	1070.444
DSS 14	70-m	35	25	33.24312	243	6	37.66244	1001.390
DSS 15	34-m HEF	35	25	18.67179	243	6	46.09762	973.211
DSS 16	26-m X-Y	35	20	29.54181	243	7	34.86090	943.977
DSS 23[2]	11-m Tilt/Az/El	35	20	22.38127	243	7	37.69312	945.351
DSS 24	34-m BWG	35	20	23.61416	243	7	30.74007	951.499
DSS 25	34-m BWG	35	20	15.40306	243	7	28.69246	959.634
DSS 26	34-m BWG	35	20	8.48118	243	7	37.14062	968.686
DSS 27	34-m HSB	35	14	17.77841	243	13	24.05838	1052.468
DSS 28[2]	34-m HSB	35	14	17.77927	243	13	15.99178	1064.647
DSS 33[2]	11-m Tilt/Az/El	–35	24	1.74505	148	58	59.13040	684.099
DSS 34	34-m BWG	–35	23	54.52383	148	58	55.07191	692.020
DSS 43	70-m	–35	24	8.72724	148	58	52.56231	688.867
DSS 45	34-m HEF	–35	23	54.44766	148	58	39.66828	674.347
DSS 46	26-m X-Y	–35	24	18.03829	148	58	59.09406	676.812
DSS 53[2]	11-m Tilt/Az/El	40	25	38.48625	355	45	1.25219	826.791
DSS 54	34-m BWG	40	25	32.23805	355	44	45.25141	837.051
DSS 55	34-m BWG	40	25	27.46525	355	44	50.52012	819.061
DSS 63	70-m	40	25	52.35510	355	45	7.16924	864.816
DSS 65	34-m HEF	40	25	37.86643	355	44	54.89535	833.830
DSS 66	26-m X-Y	40	25	47.90954	355	44	54.89653	849.874

Notes:
1. All antennas are AZ-EL type unless otherwise specified.
2. DSSs 23, 28, 33, and 53 are not presently in service.
3. Geoidal separation must be subtracted from WGS 84 height to get MSL height.

Table 6. Geocentric Coordinates for DSN Stations

Antenna[1]		Geocentric Coordinates			
Name	Description	Spin Radius (m)	Latitude (deg)	Longitude (deg)	Geocentric Radius (m)
DSS 13	34-m R & D	5215524.541	35.0660180	243.2055410	6372125.096
DSS 14	70-m	5203996.968	35.2443523	243.1104618	6371993.267
DSS 15	34-m HEF	5204234.338	35.2403129	243.1128049	6371966.511
DSS 16	26-m X-Y	5209370.721	35.1601773	243.1263503	6371965.500
DSS 23[2]	11-m Tilt/Az/El	5209499.509	35.1581927	243.1271370	6371967.573
DSS 24	34-m BWG	5209482.543	35.1585346	243.1252056	6371973.601
DSS 25	34-m BWG	5209635.569	35.1562591	243.1246368	6371982.537
DSS 26	34-m BWG	5209766.354	35.1543409	243.1269835	6371992.264
DSS 27	34-m HSB	5216079.250	35.0571452	243.2233496	6372110.240
DSS 28[2]	34-m HSB	5216089.182	35.0571457	243.2211088	6372122.418
DSS 33[2]	11-m Tilt/Az/El	5205372.623	-35.2189836	148.9830918	6371684.913
DSS 34	34-m BWG	5205508.011	-35.2169824	148.9819644	6371693.538
DSS 43	70-m	5205251.840	-35.2209189	148.9812673	6371688.998
DSS 45	34-m HEF	5205494.965	-35.2169608	148.9776856	6371675.873
DSS 46	26-m X- Y	5205075.753	-35.2234992	148.9830817	6371676.035
DSS 53[2]	11- m Tilt/Az/El	4862699.352	40.2375060	355.7503478	6370014.591
DSS 54	34-m BWG	4862832.157	40.2357726	355.7459032	6370025.490
DSS 55	34-m BWG	4862913.938	40.2344478	355.7473667	6370007.988
DSS 63	70-m	4862450.835	40.2413554	355.7519915	6370051.198
DSS 65	34-m HEF	4862717.109	40.2373343	355.7485820	6370021.694
DSS 66	26-m X-Y	4862528.402	40.2401215	355.7485824	6370036.710

Notes:

1. All antennas are AZ-EL type unless otherwise specified.
2. DSSs 23, 28, 33, and 53 are not presently in service.

Table 7. DSN Stations Location Uncertainties

Antenna[1]		Location Uncertainties (m)		
Name	**Description**	**Spin Radius**	**Longitude**	**z**
DSS 13	34-m R & D	0.025	0.036	0.031
DSS 14	70-m	0.024	0.035	0.030
DSS 15	34-m HEF	0.023	0.035	0.030
DSS 16	26-m X-Y	0.088	0.048	0.071
DSS 23[2]	11-m Tilt/Az/El	0.087	0.047	0.070
DSS 24	34-m BWG	0.029	0.036	0.033
DSS 25	34-m BWG	0.029	0.036	0.033
DSS 26	34-m BWG	0.030	0.038	0.034
DSS 27	34-m HSB	0.088	0.048	0.071
DSS 28[2]	34-m HSB	0.088	0.048	0.071
DSS 33[2]	11- m Tilt/Az/El	0.087	0.047	0.071
DSS 34	34-m BWG	0.030	0.036	0.034
DSS 43	70-m	0.026	0.035	0.032
DSS 45	34-m HEF	0.024	0.035	0.031
DSS 46	26-m X-Y	0.032	0.040	0.037
DSS 53[2]	11-m Tilt/Az/El	0.083	0.047	0.076
DSS 54	34-m BWG	0.032	0.036	0.034
DSS 55	34-m BWG	0.050	0.037	0.048
DSS 63	70-m	0.027	0.035	0.031
DSS 65	34-m HEF	0.026	0.034	0.030
DSS 66	26-m X-Y	0.083	0.047	0.076

Notes:
1. All antennas are AZ-EL type unless otherwise specified.
3. DSSs 23, 28, 33, and 53 are not presently in service.

2.2 Coverage and Mutual Visibility

The coverage and mutual visibility provided for spacecraft tracking depends on the altitude of the spacecraft, the type or types of antennas being used, the blockage of the antenna beam by the landmask and structures in the immediate vicinity of the antennas, and whether simultaneous uplink coverage is required. Receive limits are governed by the mechanical capabilities of the antennas and the terrain mask. Transmitter limits, on the other hand, are based on radiation hazard considerations to on-site personnel and the general public and are set above the terrain mask and the antenna mechanical limits.

2.2.1 Use of Transmitters Below Designated Elevation Limits

Requests for coordination to relinquish the transmitter radiation restrictions will be considered for spacecraft emergency conditions or for critical mission support requirements (conditions where low elevation or high-power transmitter radiation is critical to mission objectives). In either event, the uplink radiation power should be selected as the minimum needed for reliable spacecraft support.

2.2.1.1 Spacecraft Emergencies

The need for violation of transmitter radiation restrictions to support a spacecraft emergency will be determined by the DSN. The restrictions will be released after assuring that appropriate local authorities have been notified and precautions have been taken to ensure the safety of both on-site and off-site personnel.

2.2.1.2 Critical Mission Support

If critical mission activities require the transmitter radiation restrictions to be violated, the project is responsible for notifying the DSN through their normal point of contact three months before the activity is scheduled. The request must include enough information to enable the DSN to support it before the appropriate authorities. Requests made less than three months in advance will be supported on a best-efforts basis and will have a lower probability of receiving permission to transmit. Requests will be accepted or denied a minimum of two weeks before the planned activity.

2.2.2 Mechanical Limits on Surveillance Visibility

All DSN antennas have areas of non-coverage caused by mechanical limits of the antennas. The first area is the mechanical elevation limit, which is approximately six degrees for antennas using an azimuth-elevation mount and somewhat lower for antennas with X-Y mounts. A second area of non-coverage is the area off the end or ends of the antenna’s primary axis referred to as the *keyhole*.

2.2.2.1 Azimuth-Elevation Antennas

The keyhole of the DSN azimuth-elevation antennas is directly overhead and results from the fact that the antennas can only be moved over an arc of approximately 85 degrees in elevation. In order to track a spacecraft which is passing directly overhead, it is necessary to rotate the antenna 180 degrees in azimuth when the spacecraft is at zenith in order to continue the track. Thus, the size of the keyhole depends on how fast the antenna can be slewed in azimuth. Specifications on antenna motion are contained in module 302, Antenna Positioning. The location of the DSN antennas is such that overhead tracks are not required for spacecraft on normal planetary missions.

The DSN azimuth-elevation antennas have an additional restriction on antenna motion caused by the routing path of cables and hoses between the fixed and rotating portions of the antenna. This azimuth cable wrap has no effect on surveillance visibility but does place a restriction on the time between tracks due to the requirement to unwind the cables. Table 8 provides the approximate cable wrap limits for the DSN azimuth-elevation antennas.

2.2.2.2 X-Y Antennas

The DSN 26-m X-Y antennas (DSS 16, 46, and 66) have two keyholes caused by requirements for mechanical clearance in the antenna structure. The keyholes are located directly to the east and west of the 26-m antennas.

2.2.2.3 Tilt-Azimuth-Elevation Antennas

The DSN 11-m antennas (DSS 23, 33, and 53) have a keyhole above each antenna, which is offset from zenith by 7-degrees. The location of this keyhole is set before each pass to a position that will provide clearance between the keyhole and the scheduled track.

2.2.3 Coverage Charts

The following figures provide examples of coverage for various combinations of stations, spacecraft altitudes, and type of support. These figures were plotted by a program written as a collection of Microsoft Excel 97/98 macros. This program is available for download (1.7 Mbytes) from the 810-005 web site (http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/) and includes the antenna coordinates and mask data used to create the figures.

2.2.3.1 70-m Subnet Receive Coverage of Planetary Spacecraft

Figure 2 illustrates the receive coverage of planetary spacecraft by the DSN 70-m antenna subnet. The small ovals at each antenna location on the figure represent the 70-m antenna keyholes above each station and are approximately to scale.

Table 8. Approximate Cable Wrap Limits for Azimuth-Elevation Antennas

Antenna		Azimuth Position (Degrees)		
Name(s)	**Description**	**Center of Wrap**	**CW Limit**	**CCW Limit**
DSS 14, 63	70-m	45	310	140
DSS 43	70-m	135	40	230
DSS 15, 65	34-m HEF	135	360	270
DSS 45	34-m HEF	45	270	180
DSS 24, 25, 26, 54, 55	34-m BWG	135	360	270
DSS 34	34-m BWG	45	270	180
DSS 27	34-m HSB	135	360	270
DSS 23, 33, 53	11-m	0	380	(-) 380

2.2.3.2 70-m Subnet Transmit Coverage of Planetary Spacecraft

Figure 3 illustrates the transmit coverage of planetary spacecraft by the DSN 70-m antenna subnet using a 10.4-degree transmit elevation limit at DSS 14 and a 10.2-degree transmit elevation limit at DSS 43 and DSS 63. The small ovals at the antenna locations on the figure represent the 70-m antenna keyholes. The reduced coverage to the west of DSS 63 is caused by the need to have a 20.2-degree elevation limit to protect the high ground to the northwest of the station.

2.2.3.3 34-m HEF Subnet Receive Coverage of Planetary Spacecraft

Figure 4 illustrates the receive coverage of planetary spacecraft by the DSN 34-m HEF antenna subnet. The keyhole above each 34-m HEF antenna is very small and is somewhat exaggerated for clarity on the maps. This chart is very similar to Figure 2 but is included to show that the location of DSS 65 shifts the apparent position of the high ground to the north and west of where it is observed from DSS 63.

2.2.3.4 34-m HEF Subnet Transmit Coverage of Planetary Spacecraft

Figure 5 illustrates the transmit coverage of planetary spacecraft by the DSN 34-m HEF antenna subnet using a 10.6-degree transmit elevation limit at DSS 15, a 10.5-degree transmit limit at DSS 45, and a 10.3-degree limit at DSS 65. As is the case in Figure 4, the size of the circles used to indicate the keyholes on the map are larger than the actual size of the 34-m HEF antenna keyholes. Protection of the high ground at DSS 65 is provided by disabling the transmitter between 327.4 and 358.6 degrees azimuth.

2.2.3.5 34-m BWG Antennas Receive Coverage of Planetary Spacecraft

Figure 6 illustrates the receive coverage of planetary spacecraft by the DSN 34-m BWG antennas. As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes. This chart is very similar to Figures 2 and 4 but is included to show that the location of DSS 54 shifts the apparent position of the high ground to where it does not significantly affect tracking coverage.

2.2.3.6 34-m BWG Antennas Transmit Coverage of Planetary Spacecraft

Figures 7 illustrates the transmit coverage of planetary spacecraft by a subnet of 34-m BWG antennas composed of DSS 24, 34, and 54. As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes. Protection of the high ground at DSS 54 is provided by placing a 13.6-degree lower elevation limit on the transmitter between 267 and 3 degrees azimuth. DSS 55 is sited south-east of DSS 54 at a slightly lower elevation. To allow an adequate clearance above DSS 54 for the DSS 55 transmitter pencil beam, an 18-degree lower elevation limit is placed on the DSS 55 transmitter between 294 and 360 degrees. The difference in coverage obtained from a subnet of BWG antennas composed of DSS 26, 34, and 55 is shown in Figure 8.

2.2.3.7 26-m Subnet Receive Coverage of Earth Orbiter Spacecraft

Figure 9 illustrates the receive coverage of Earth-orbiter spacecraft at altitudes of 200 km, 1000 km, and 5000 km by the DSN 26-m antenna subnet. This chart can also be used when the 34-m HSB antenna, DSS 27, is substituted for the Goldstone 26-m antenna. DSS 27 is collocated with an inactive antenna, DSS 28, approximately 14.5 km southeast of DSS 16. The inactive antenna blocks reception to the west in the same place and approximately to the same extent as the west keyhole of DSS 16. DSS 27 also has a very small keyhole directly overhead.

2.2.3.8 26-m Subnet Transmit Coverage of Earth Orbiter Spacecraft

Figure 10 illustrates the transmit coverage of Earth-orbiter spacecraft at altitudes of 200 km, 1000 km, and 5000 km by the DSN 26-m antenna subnet. This chart is similar to Figure 8. However, the limits placed on transmitter operation in order to clear terrain and structures are clearly visible.

2.2.3.9 34-m BWG Antennas Receive Coverage of Earth Orbiter Spacecraft

Figure 11 illustrates the receive coverage of Earth-orbiter spacecraft by the DSN 34-m BWG antennas at altitudes of 500 km, 5000 km, and geosynchronous (35789 km). As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes

2.2.3.10 34-m BWG Antennas Receive Coverage of Earth Orbiter Spacecraft

Figure 12 illustrates the transmit coverage of Earth-orbiter spacecraft by the DSN 34-m BWG antennas. As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes. Protection of the high ground at DSS 54 and 55 is provided by a 13.6-degree lower elevation limit between 267 and 3 degrees azimuth.

2.2.4 Horizon Masks and Antenna Limits

Figures 13 through 28 show the horizon mask and transmitter limits for all DSN stations. The transmitter limits are identified as the L/P (low power) transmitter mask (or the H/P (high power) transmitter mask depending on the type of transmitter that is available. Only the 70-m stations have both L/P and H/P transmitters but all stations use the same elevation limits for all their transmitters. In general, the transmitter limit is set at approximately 10.2 degrees unless a higher limit is required to clear terrain or some other obstruction. The masks and limits are the ones used to establish the coverage depicted in Figures 2 through 12. Each chart shows antenna coordinates in two coordinate systems. For all antennas except those with X-Y mounts, the coordinate systems are azimuth-elevation and hour angle-declination. The antennas with X-Y mounts show azimuth-elevation and X-Y coordinates.

Charts showing hour angle-declination coordinates can be used to provide an elevation profile (for estimating antenna gain and noise temperature) for spacecraft at planetary distances where the declination remains constant for an entire tracking pass. The hour angle curves on these charts have been spaced at increments of 15 degrees so that pass length may conveniently be estimated. These figures were plotted by a program written as a collection of Microsoft Excel 97/98 macros. This program is available for download (1.1 Mbytes) from the 810-005 web site (http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/). This file also contains the land mask data, which can be used to accurately calculate spacecraft rise and set times.

3 Proposed Capabilities

3.1 DSS 65 Relocation

The DSS 65 antenna has experienced differential settling of its foundation since its construction. Attempts to ameliorate the situation have proven unsuccessful and a decision has been made to construct a new foundation approximately 53 m east of the present location and move the antenna. The coverage capability and horizon mask are not expected to be changed significantly by the move.

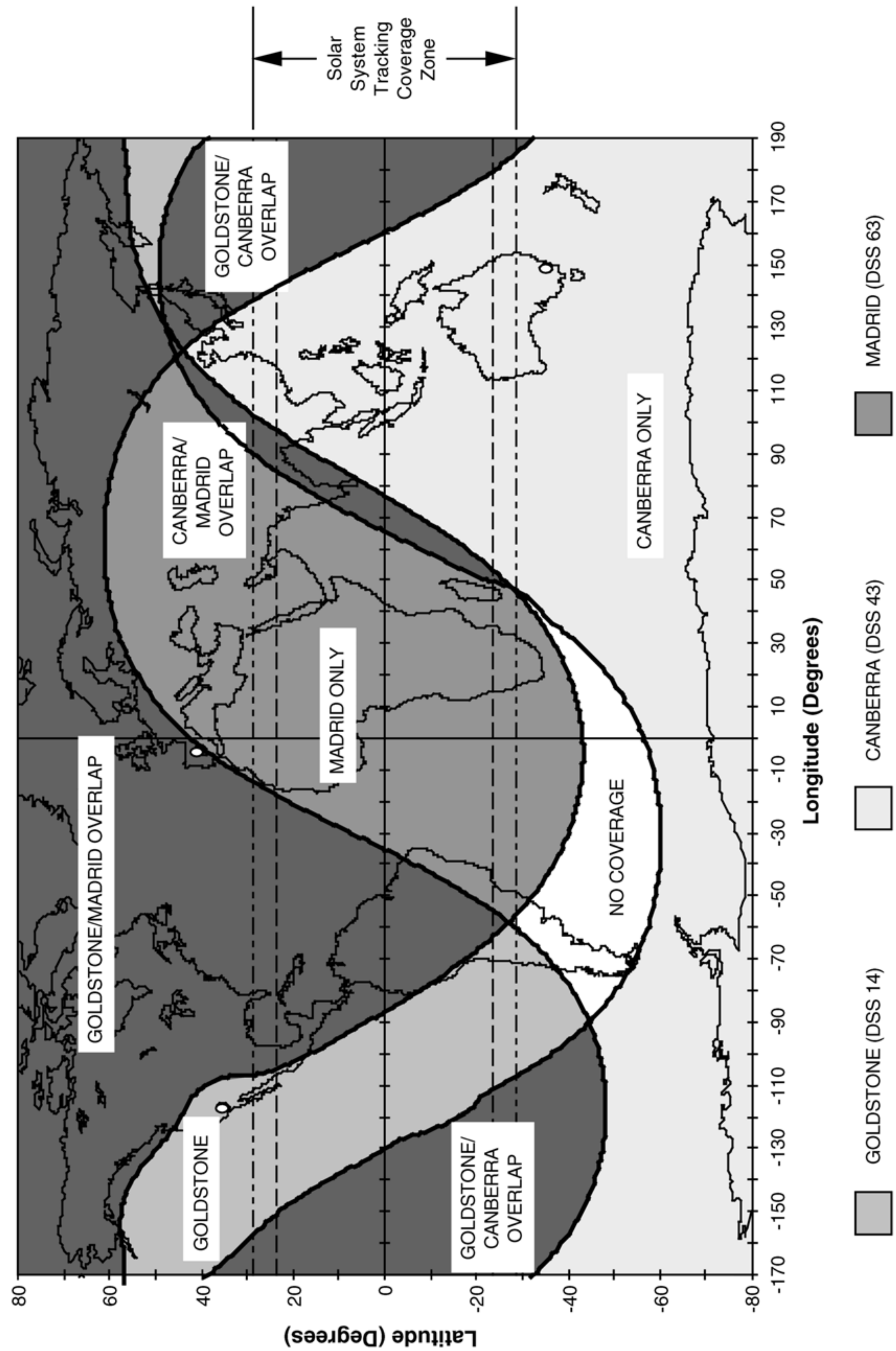

Figure 2. DSN 70-m Subnet Receive Coverage, Planetary Spacecraft

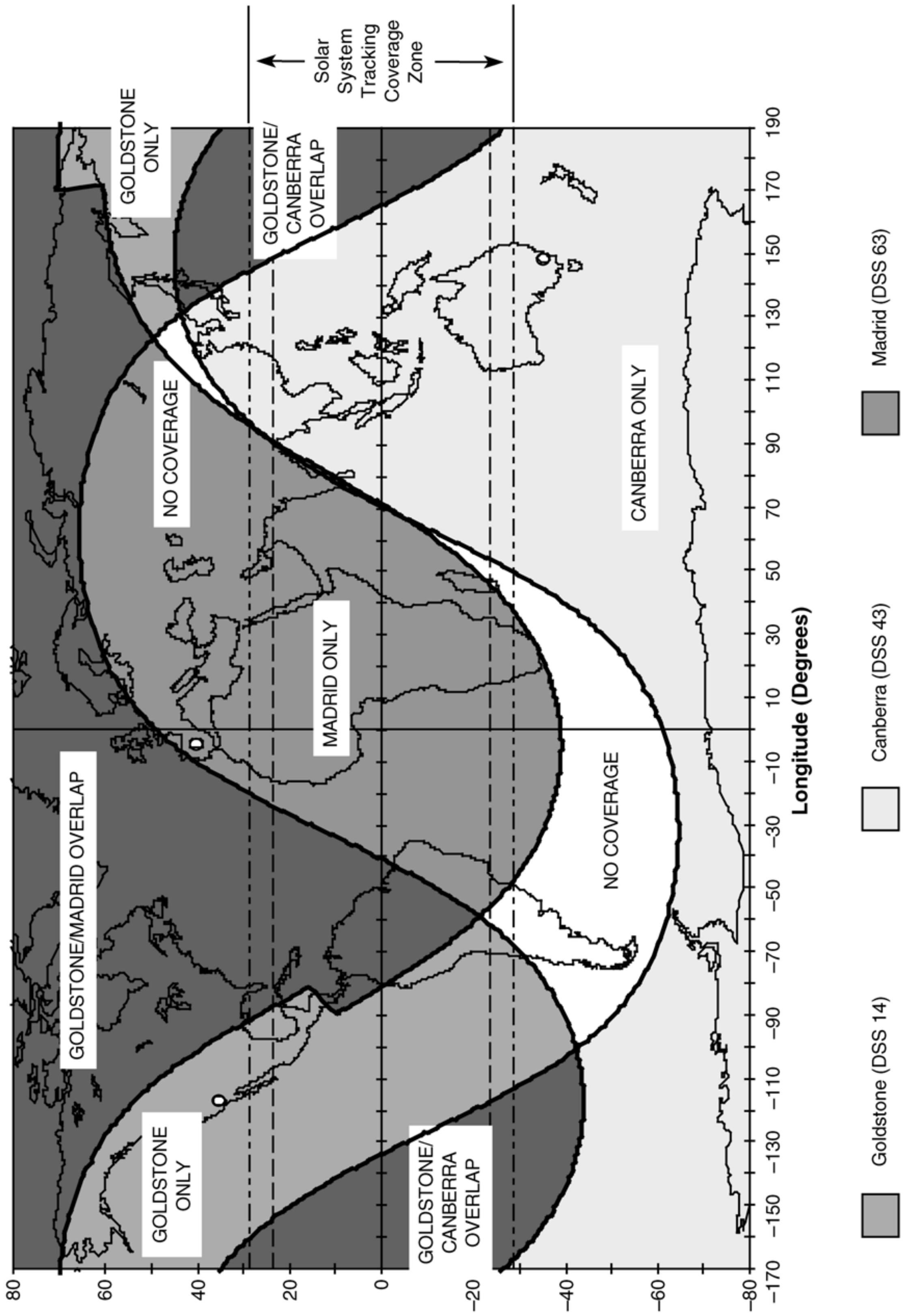

Figure 3. DSN 70-m Subnet Transmit Coverage, Planetary Spacecraft.

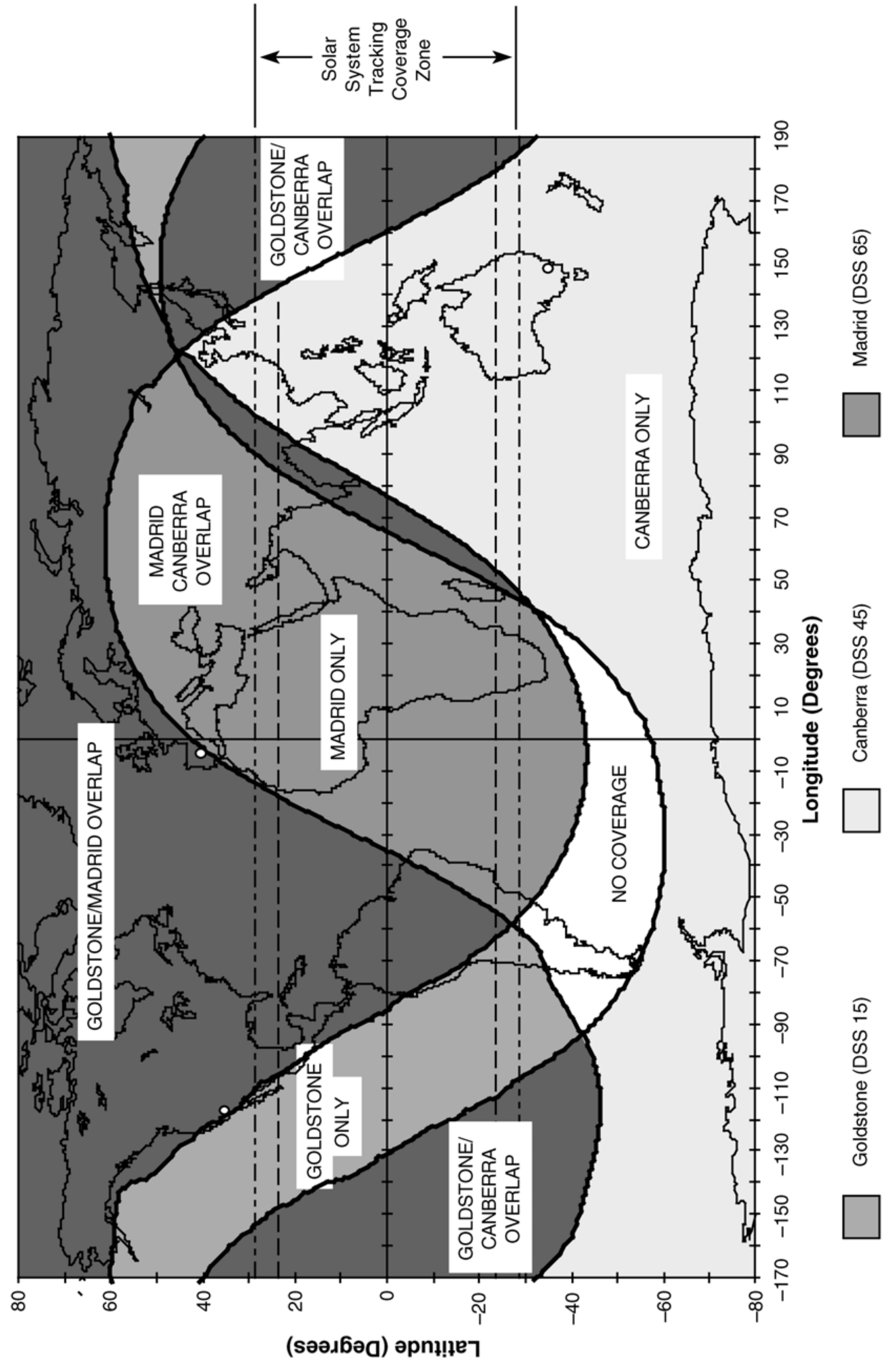

Figure 4. DSN 34-m HEF Subnet Receive Coverage, Planetary Spacecraft.

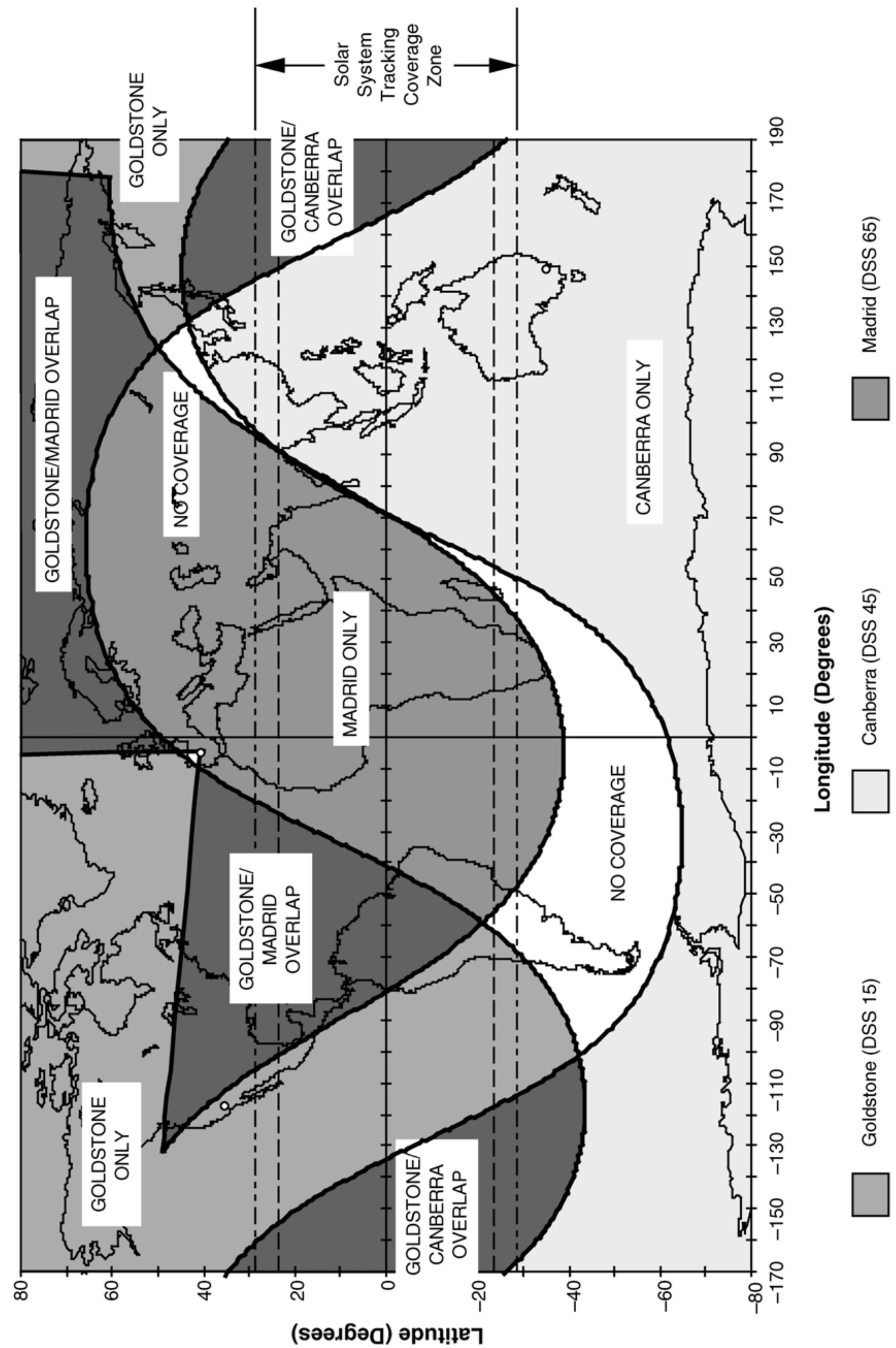

Figure 5. DSN 34-m HEF Subnet Transmit Coverage, Planetary Spacecraft

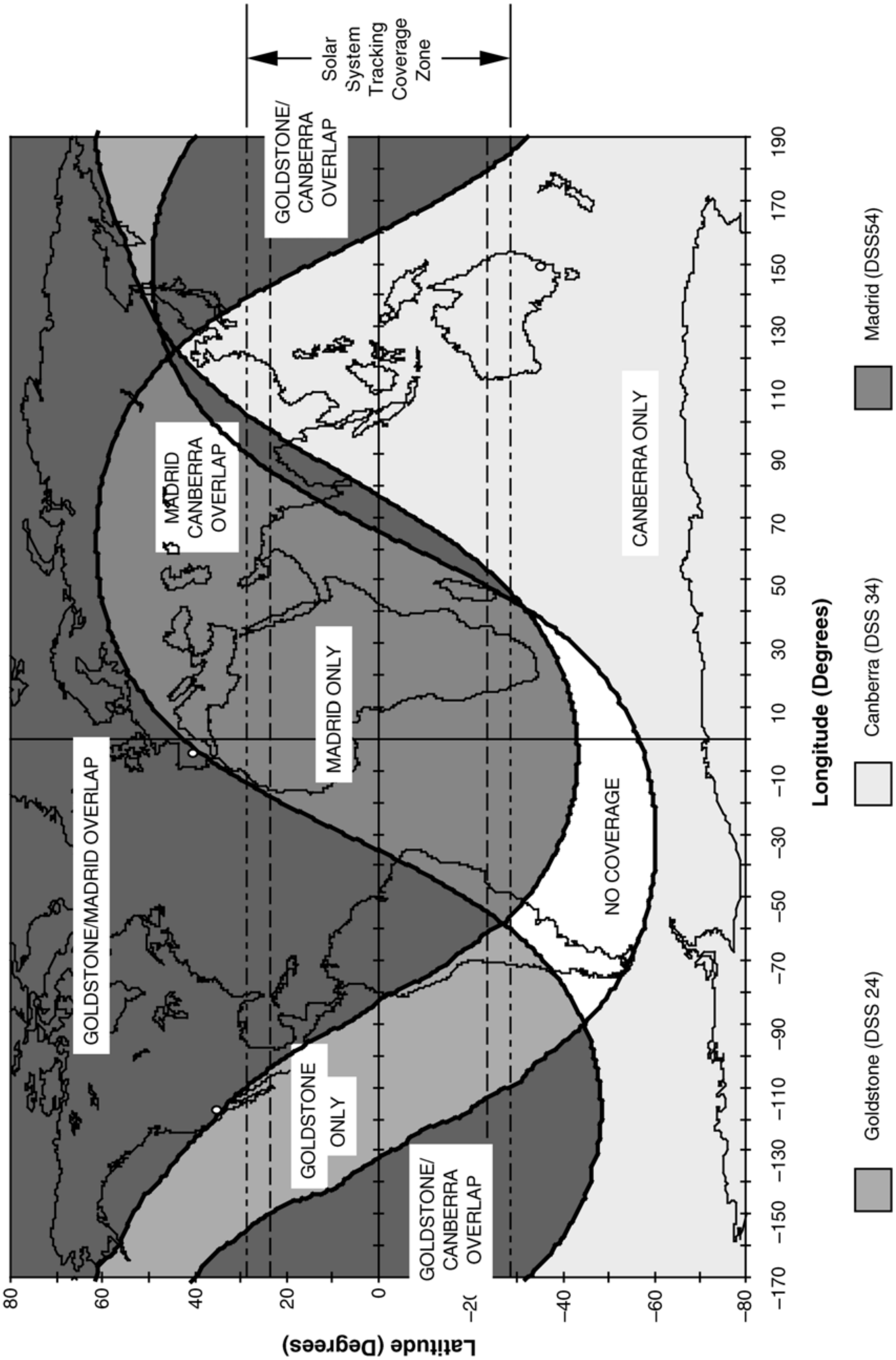

Figure 6. DSN 34-m BWG Antennas Receive Coverage, Planetary Spacecraft

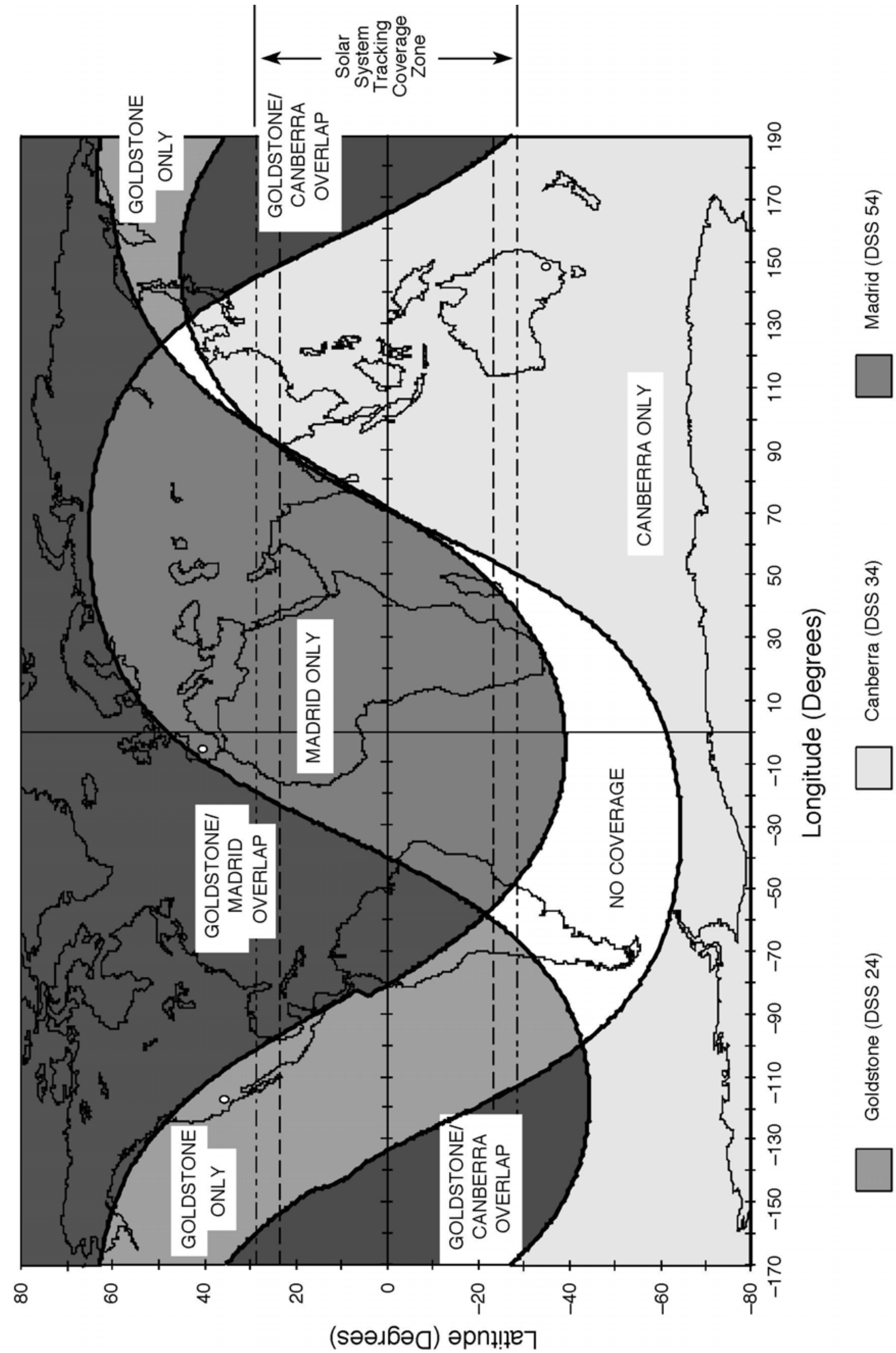

Figure 7. DSN 34-m BWG Antennas Transmit Coverage, Planetary Spacecraft, Using DSS 26, 34, and 55.

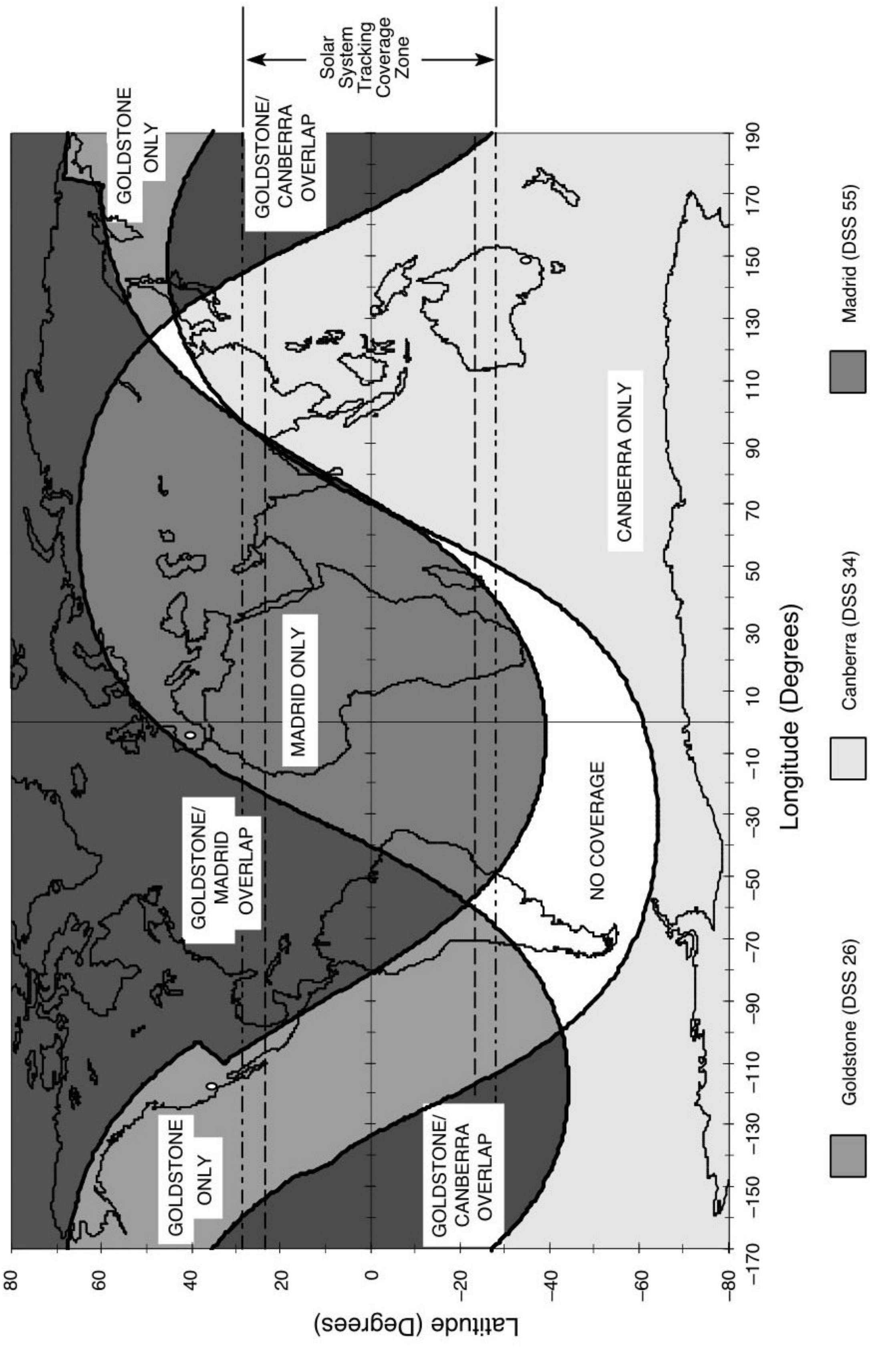

Figure 8. DSN 34-m BWG Antennas Transmit Coverage, Planetary Spacecraft, Using DSS 24, 34, and 54.

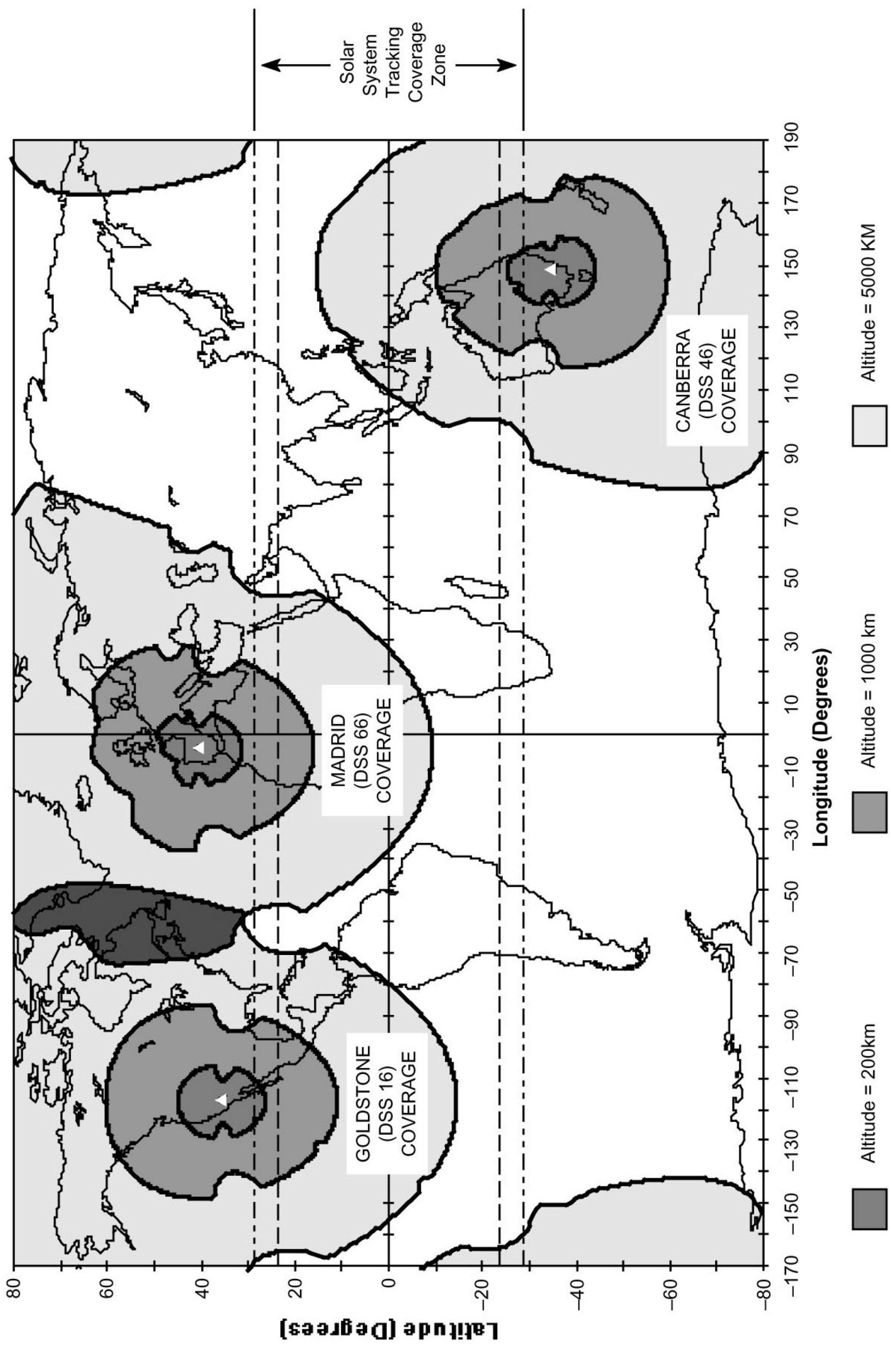

Figure 9. DSN 26-m Subnet Receive Coverage, Earth Orbiter Spacecraft.

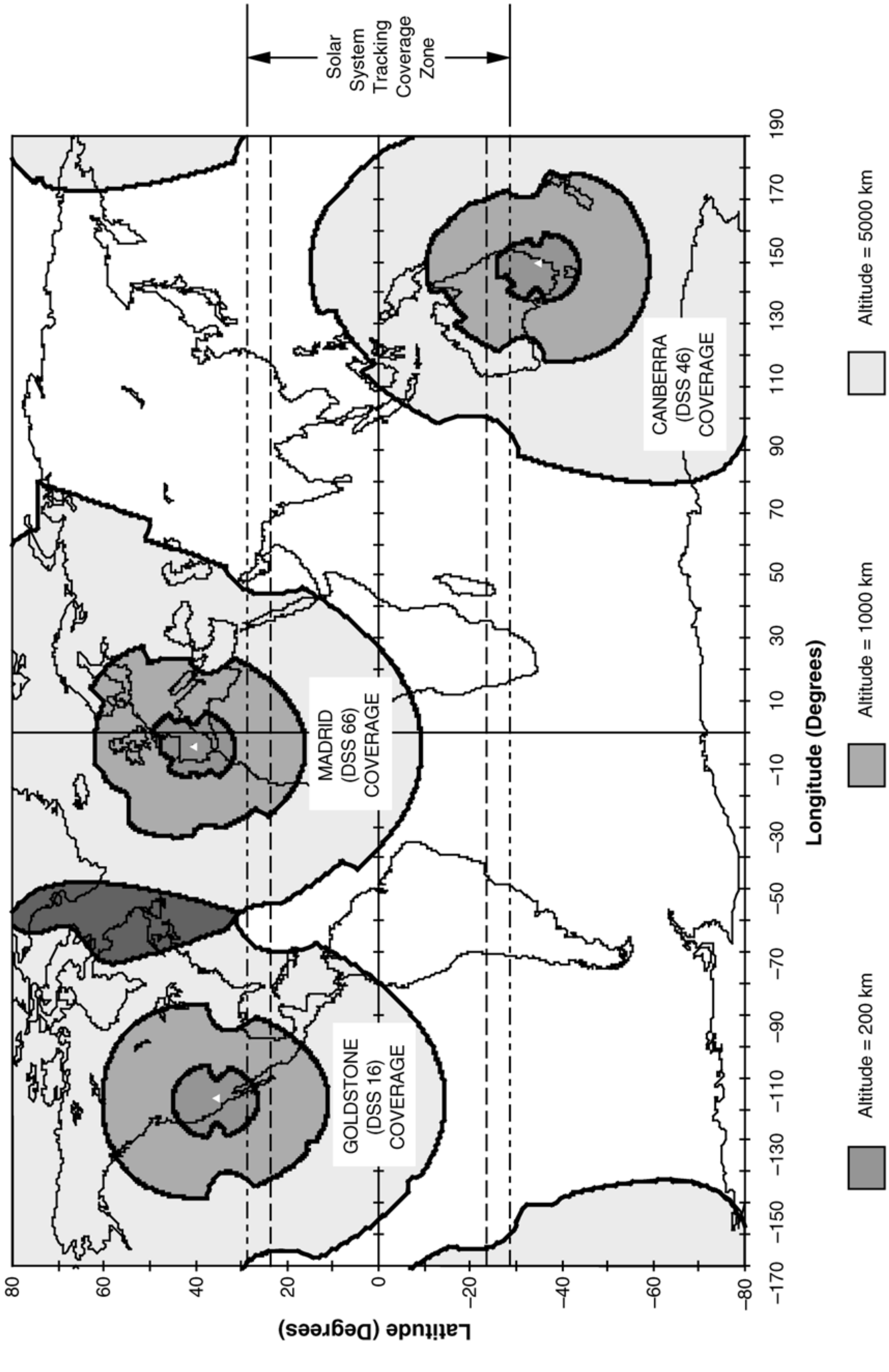

Figure 10.DSN 26-m Subnet Transmit Coverage, Earth Orbiter Spacecraft

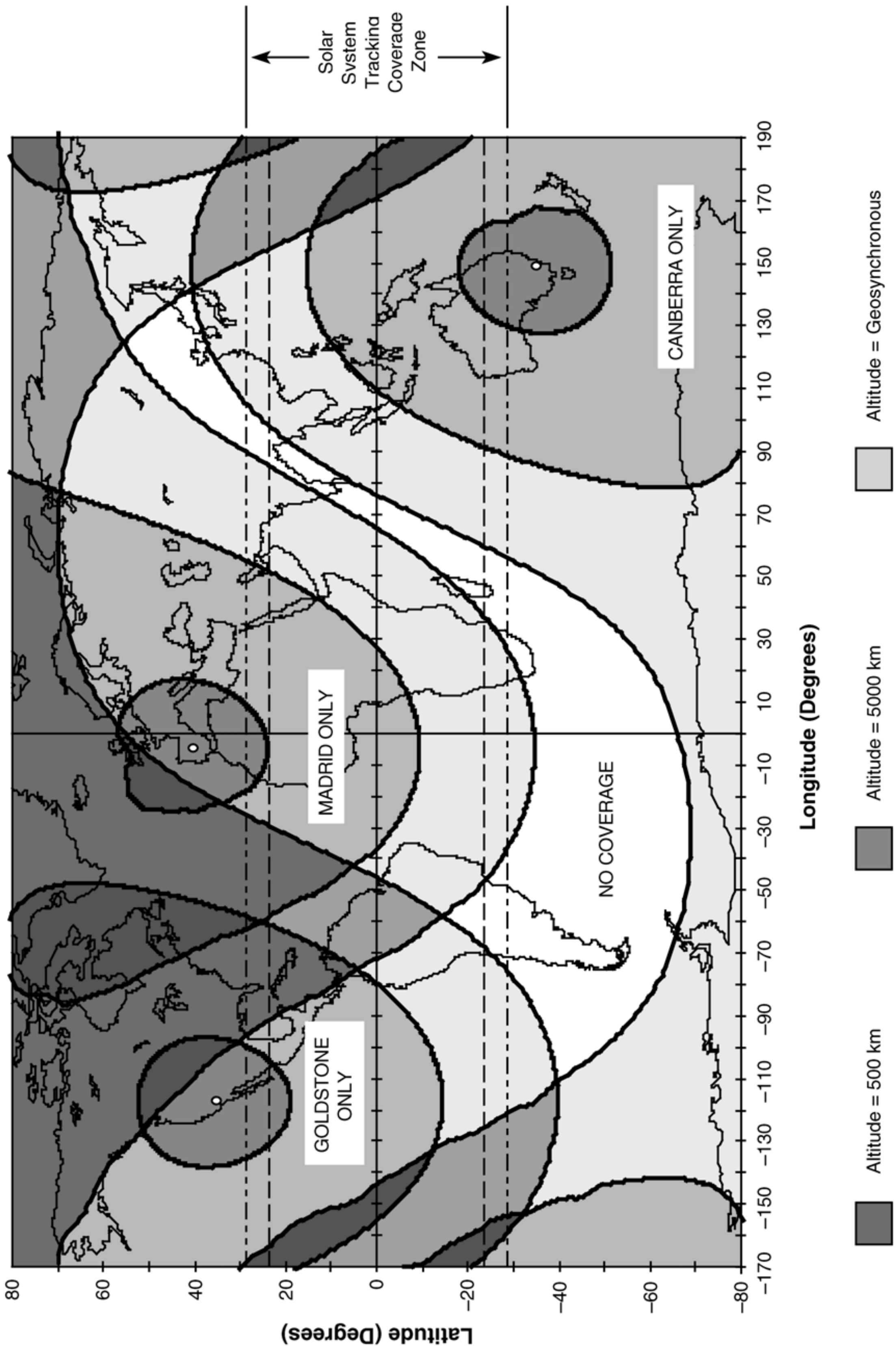

Figure 11. DSN 34-m BWG Antennas Receive Coverage, Earth Orbiter Spacecraft

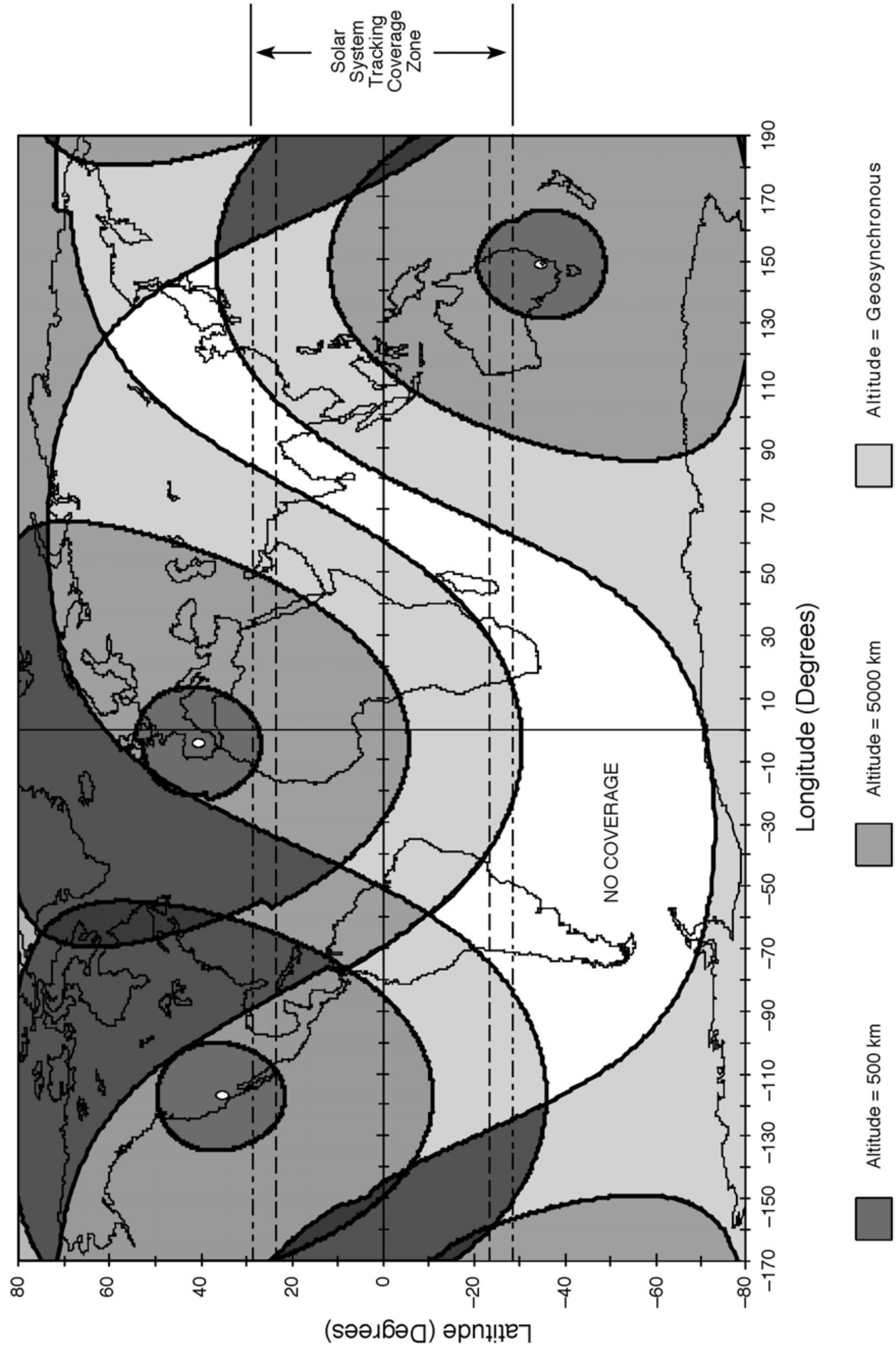

Figure 12 DSN 34-m BWG Antennas Transmit Coverage, Earth-Orbiter Spacecraft

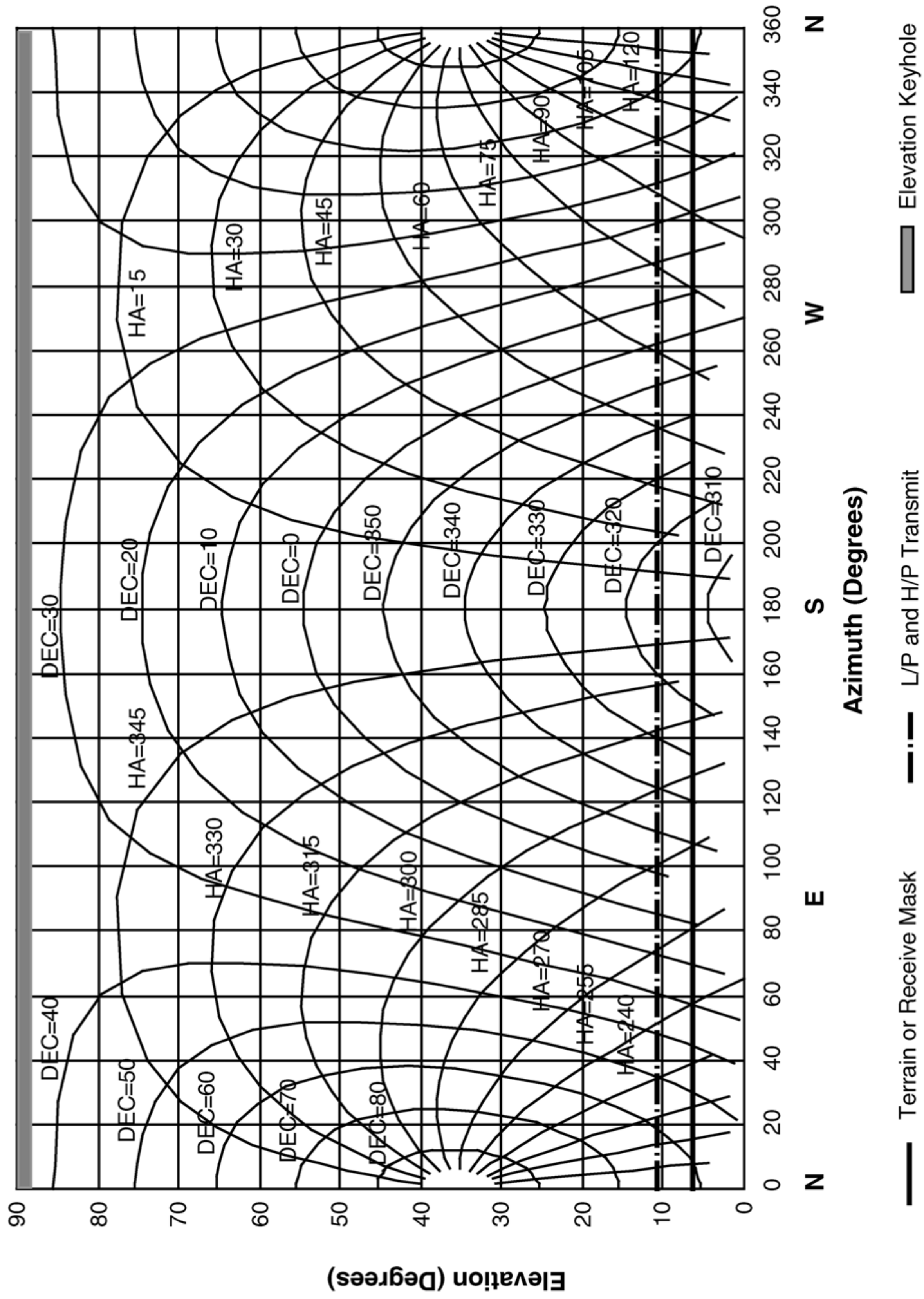

Figure 13. DSS 14 Hour-Angle and Declination Profiles and Horizon Mask

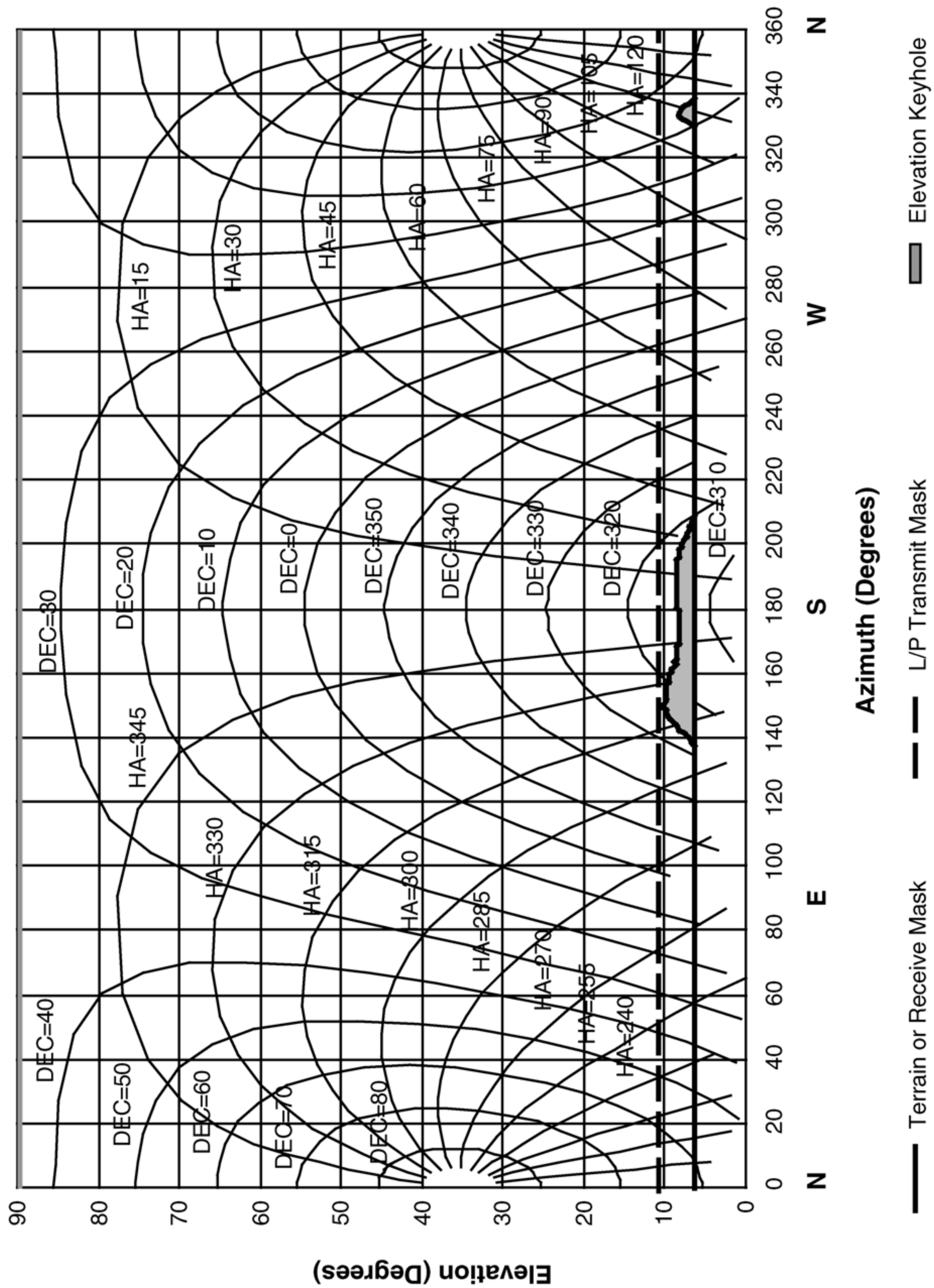

Figure 14. DSS 15 Hour-Angle and Declination Profiles and Horizon Mask

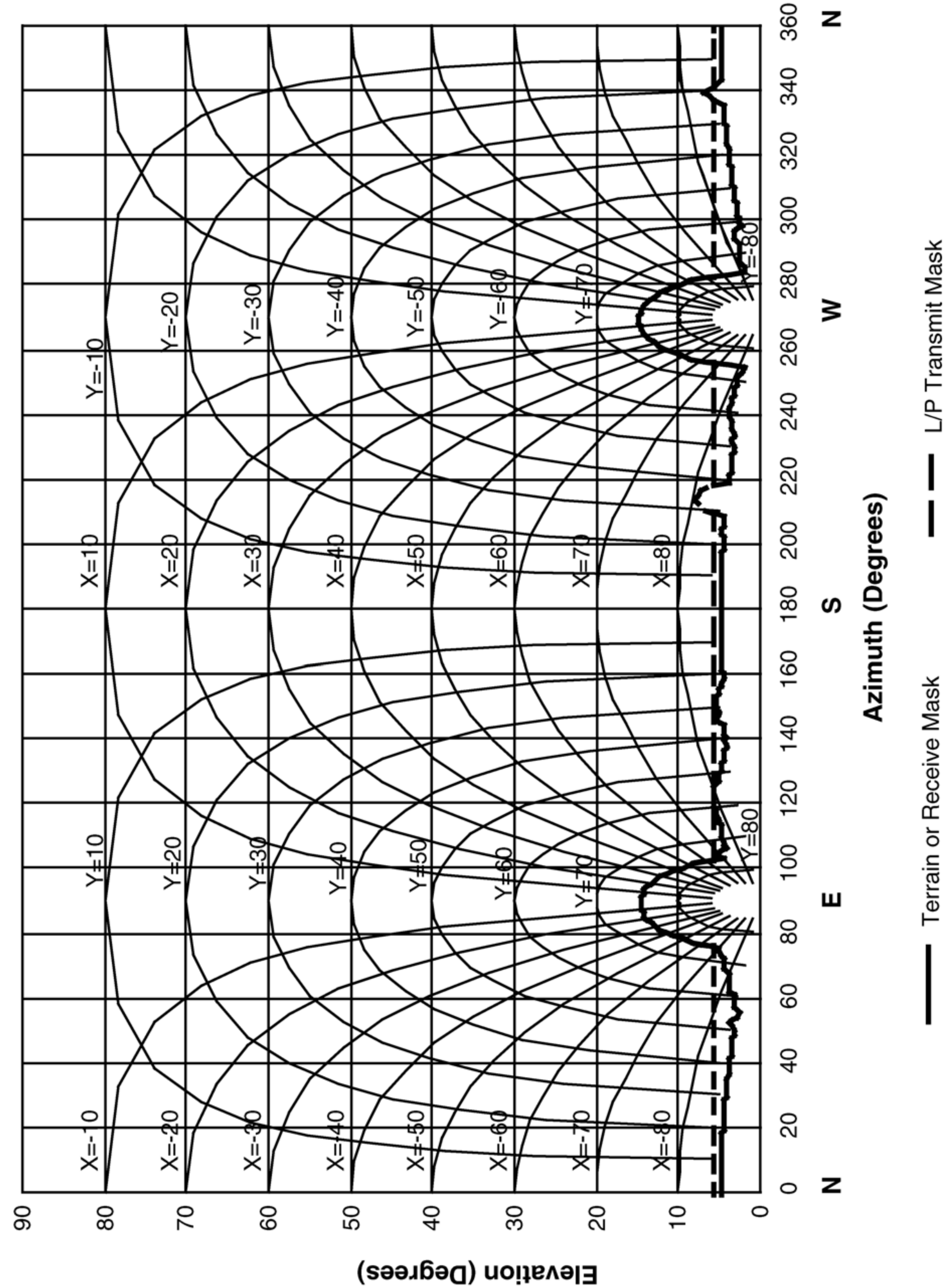

Figure 15. DSS 16 X-Y Profiles and Horizon Mask

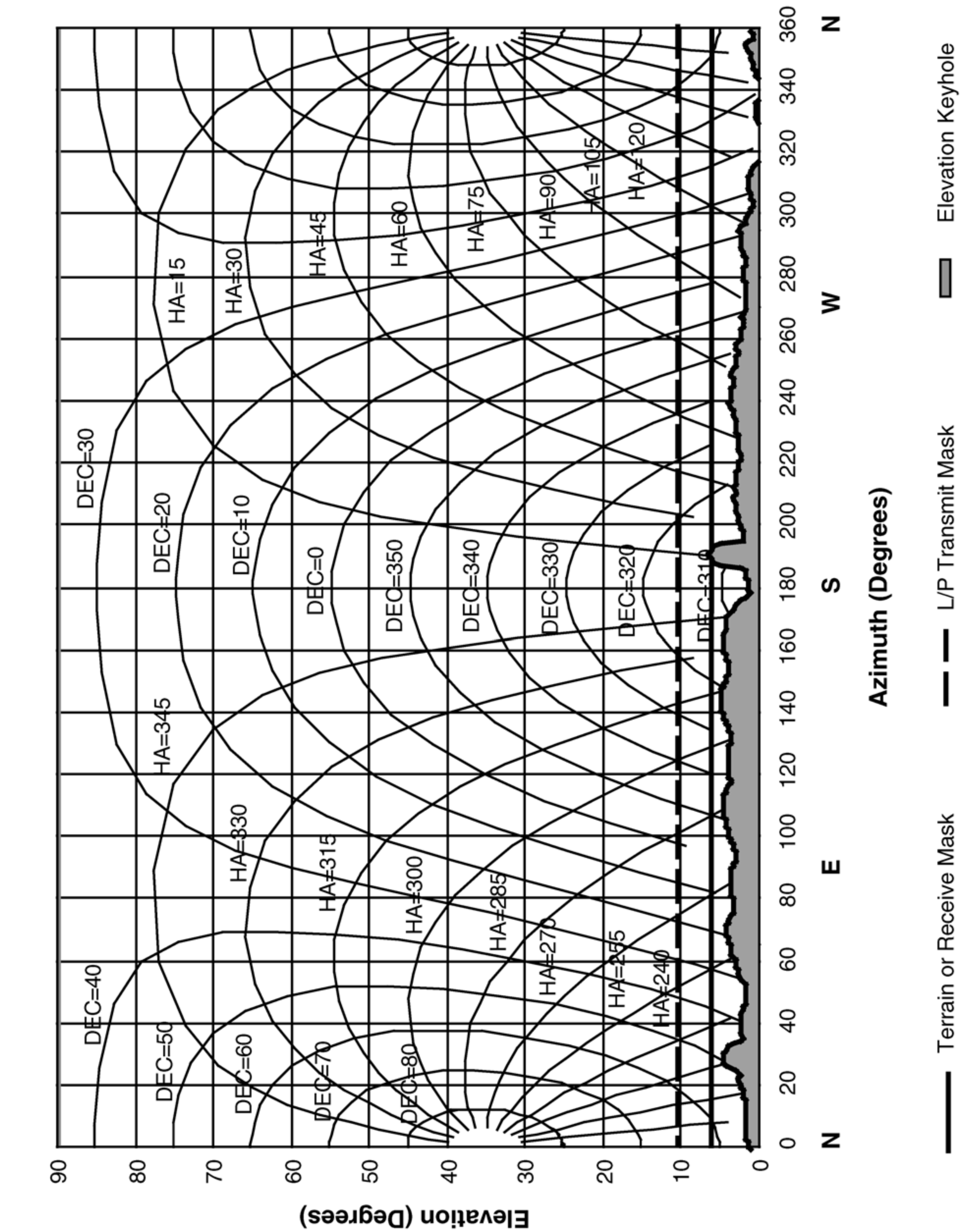

Figure 16. DSS 24 Hour-Angle and Declination Profiles and Horizon Mask

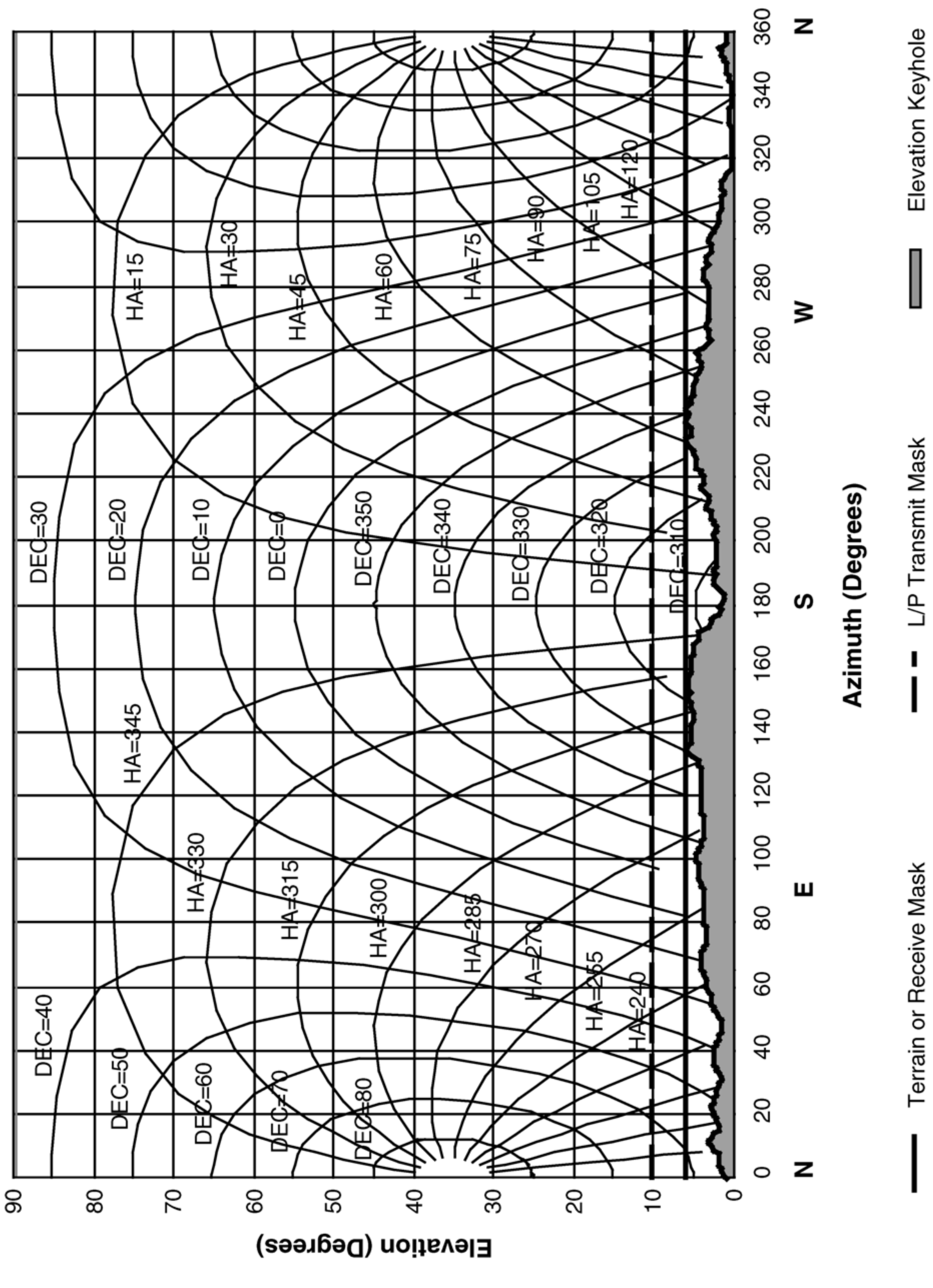

Figure 17. DSS 25 Hour-Angle and Declination Profiles and Horizon Mask

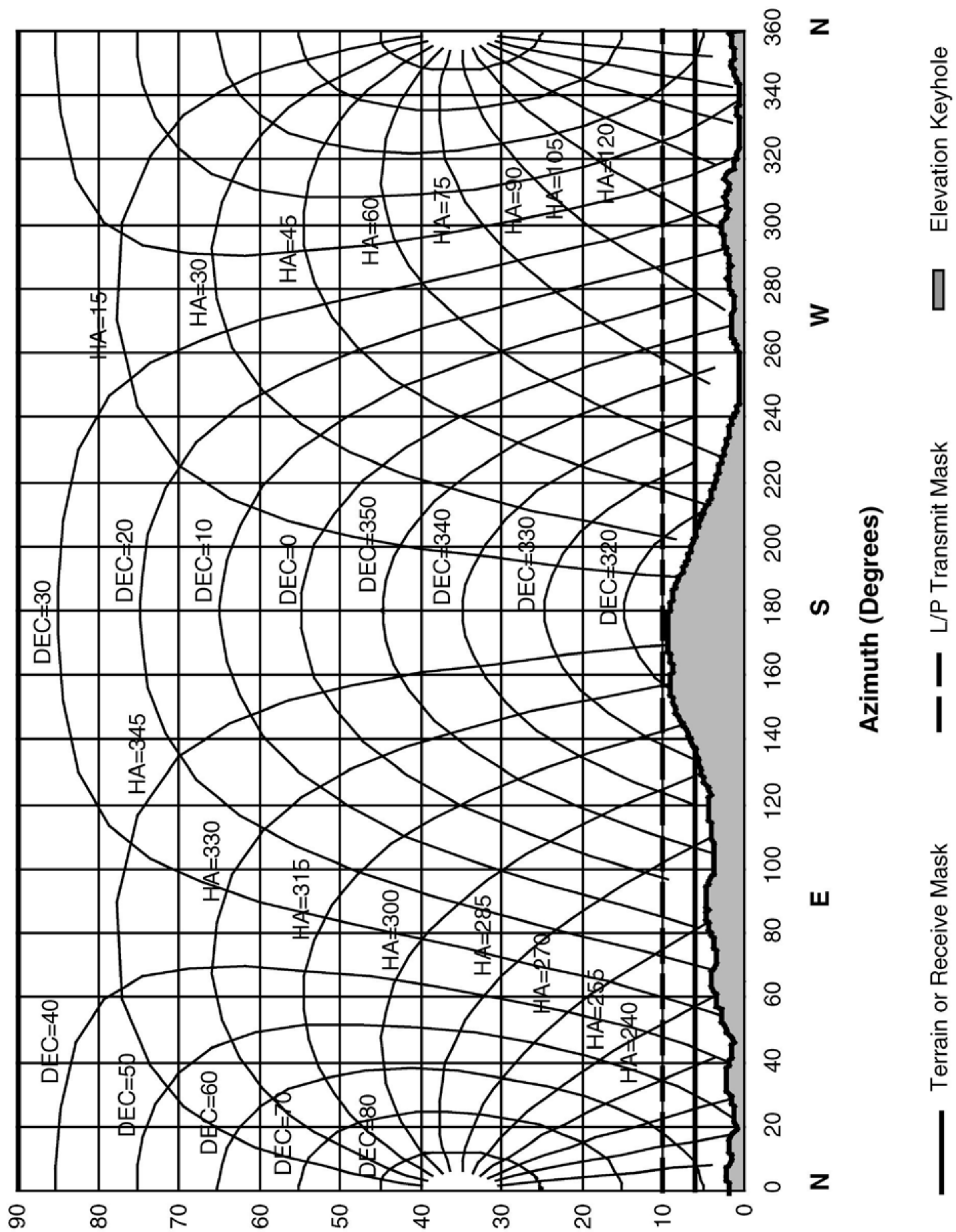

Figure 18. DSS 26 Hour-Angle and Declination Profiles and Horizon Mask

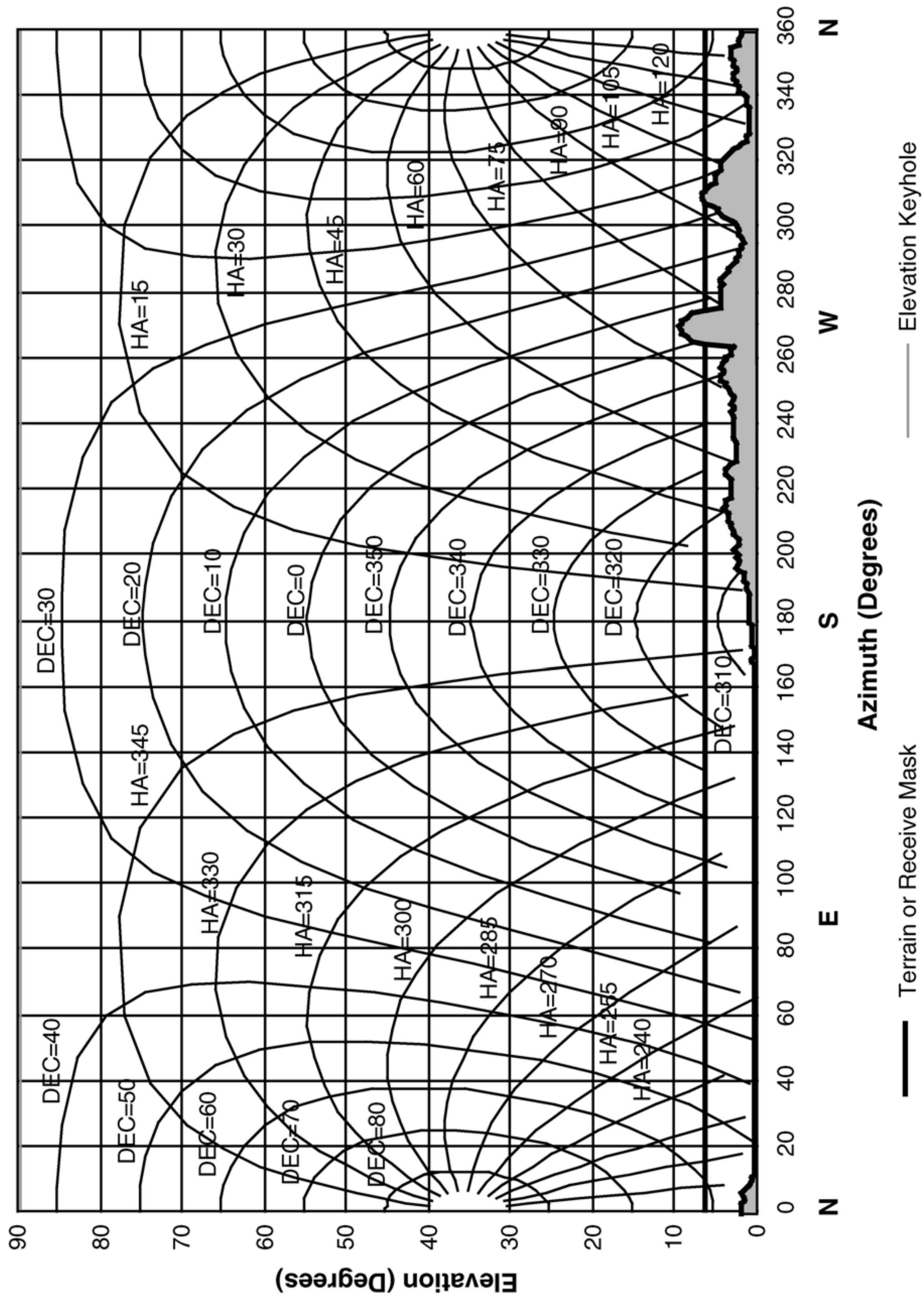

Figure 19. DSS 27 Hour-Angle and Declination Profiles and Horizon Mask.

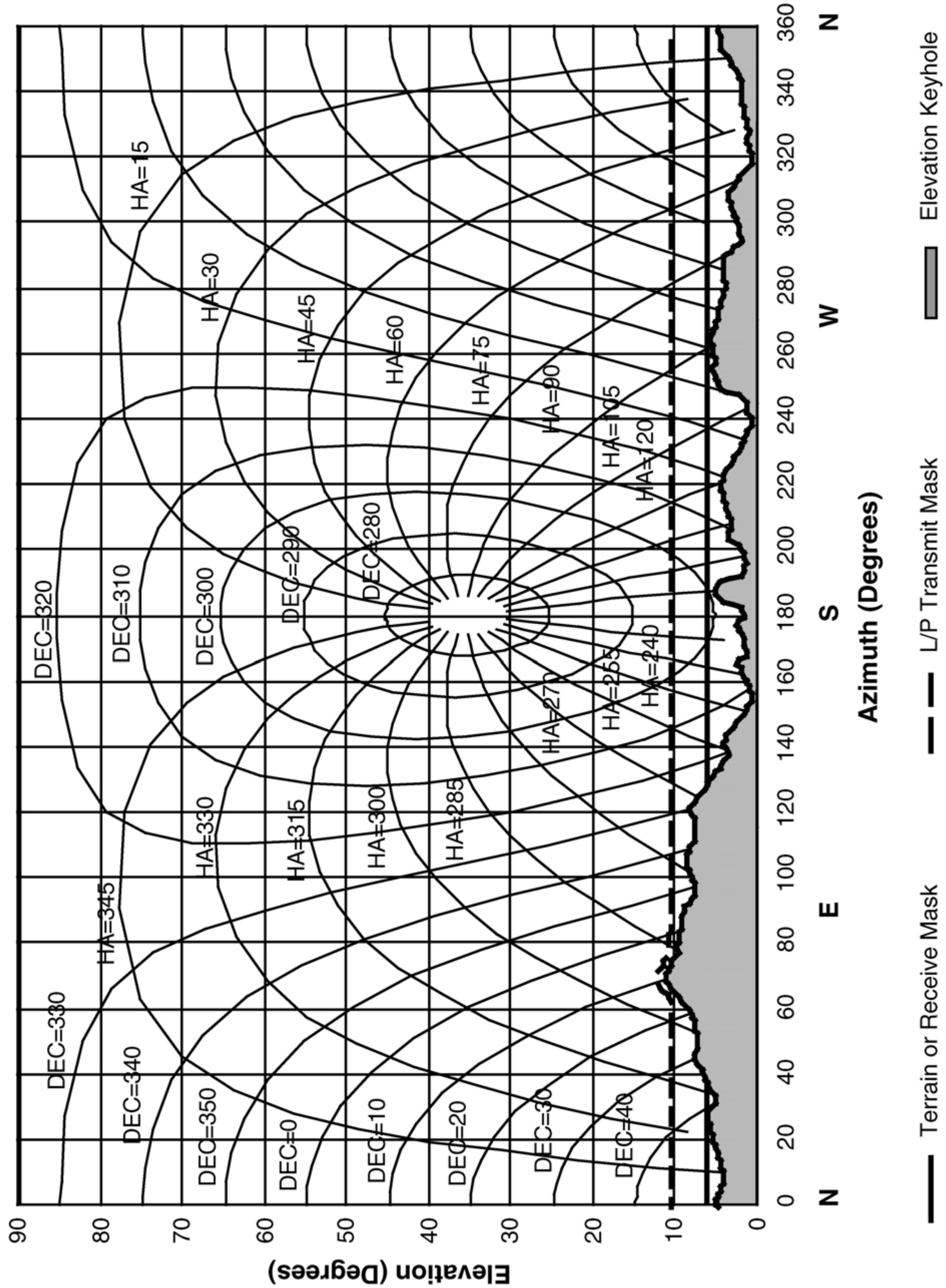

Figure 20. DSS 34 Hour-Angle and Declination Profiles and Horizon Mask

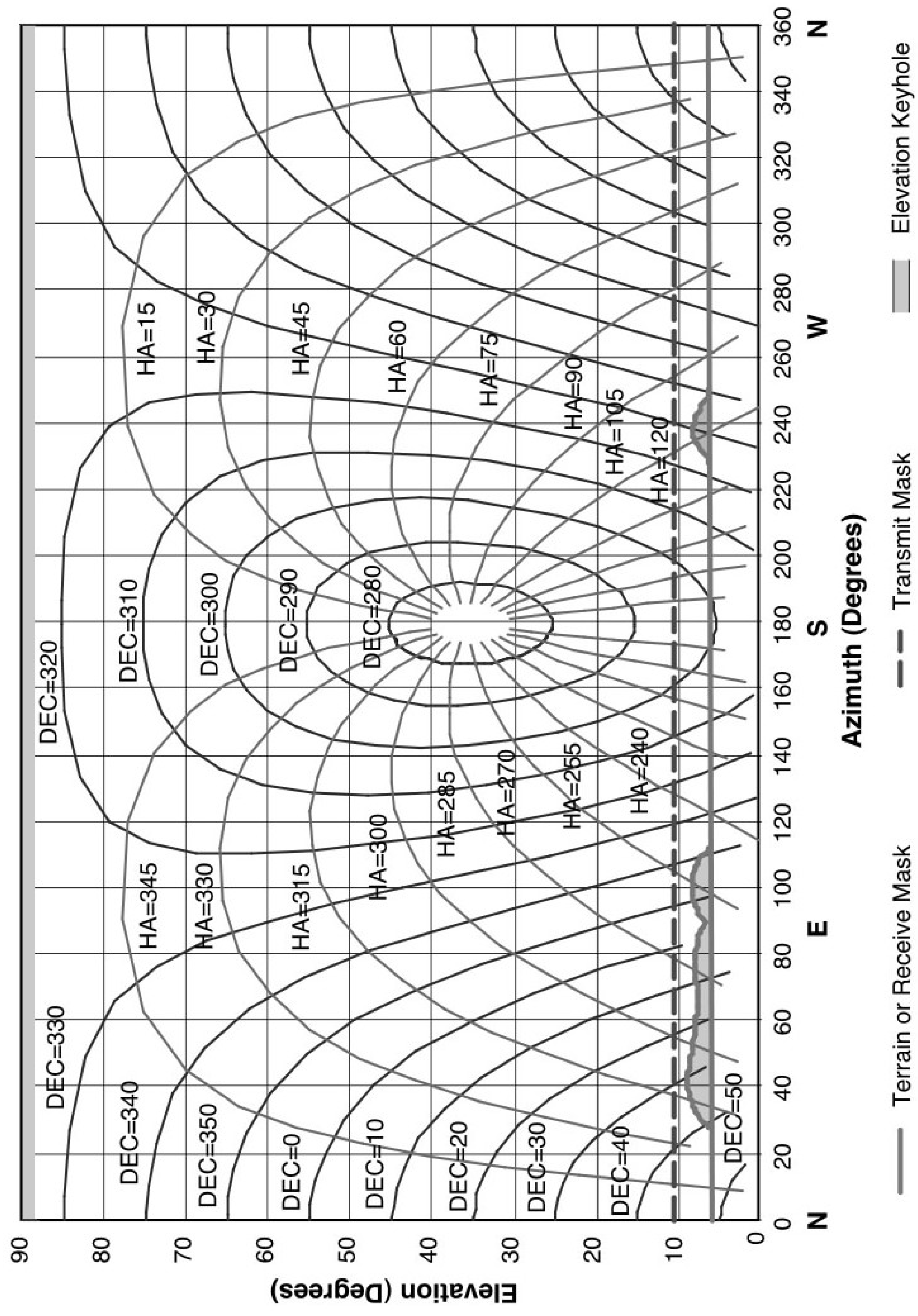

Figure 21. DSS 43 Hour-Angle and Declination Profiles and Horizon Mask

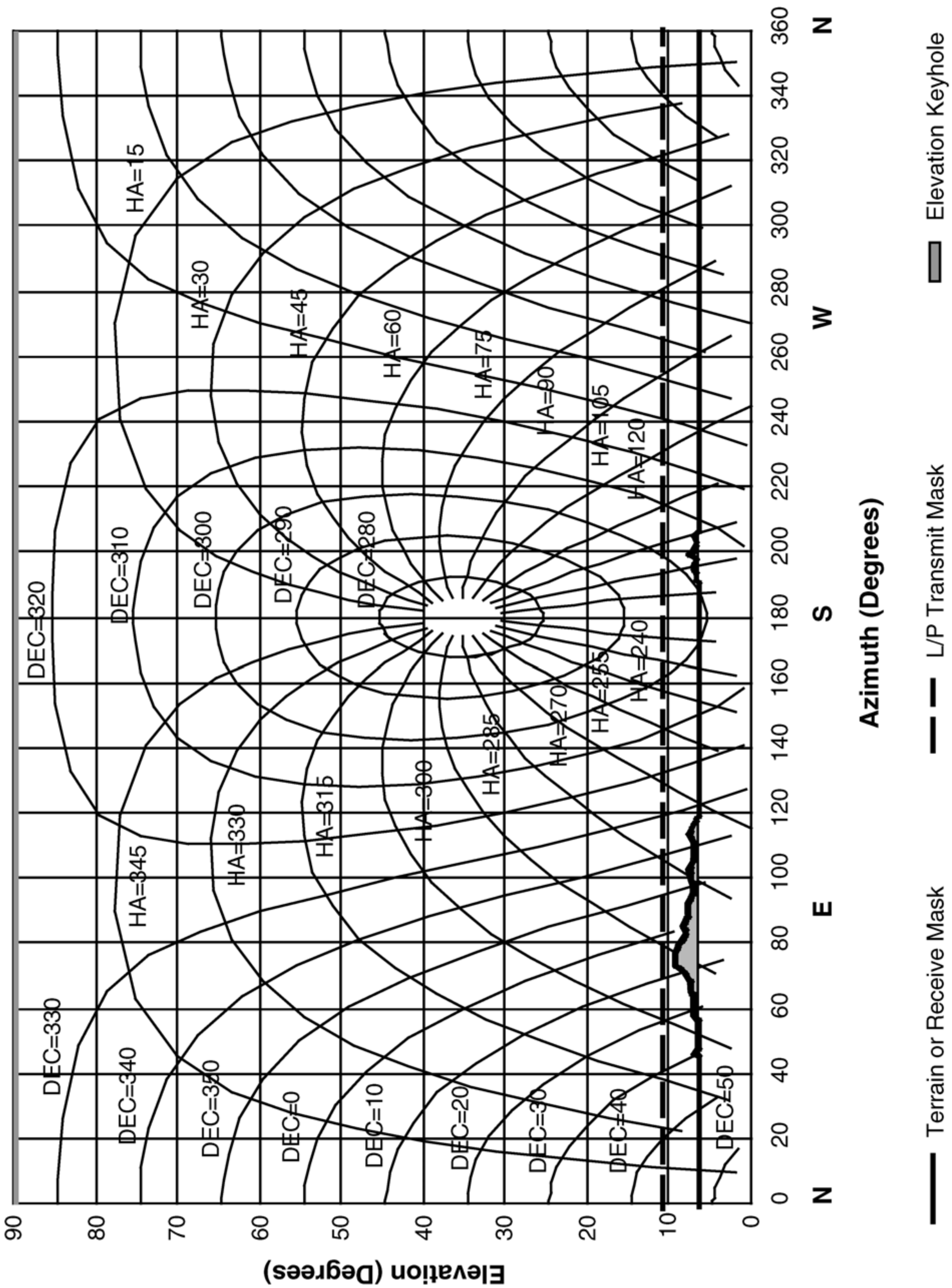

Figure 22. DSS 45 Hour-Angle and Declination Profiles and Horizon Mask

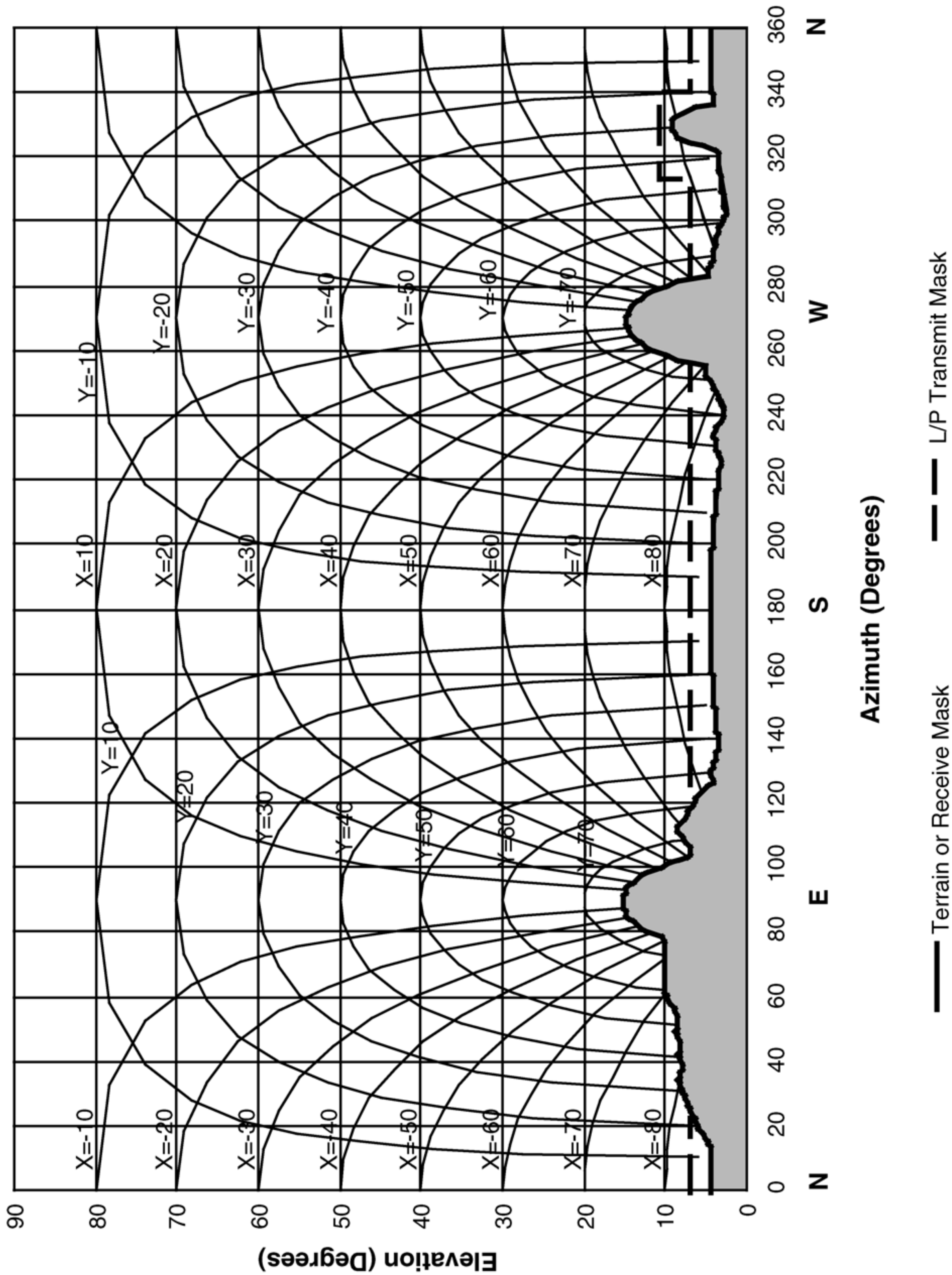

Figure 23. DSS 46 X-Y Profiles and Horizon Mask

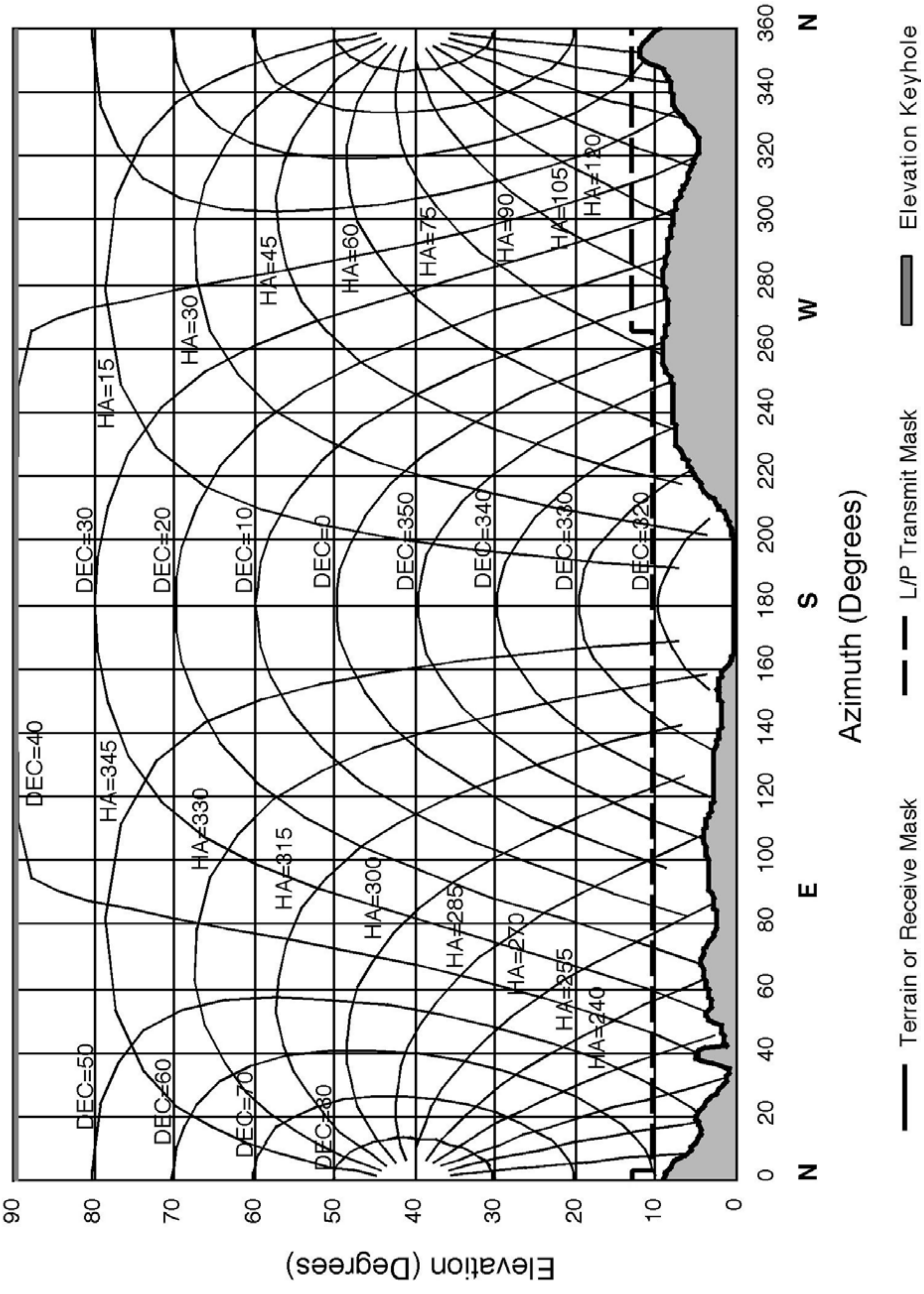

Figure 24. DSS 54 Hour-Angle and Declination Profiles and Horizon Mask

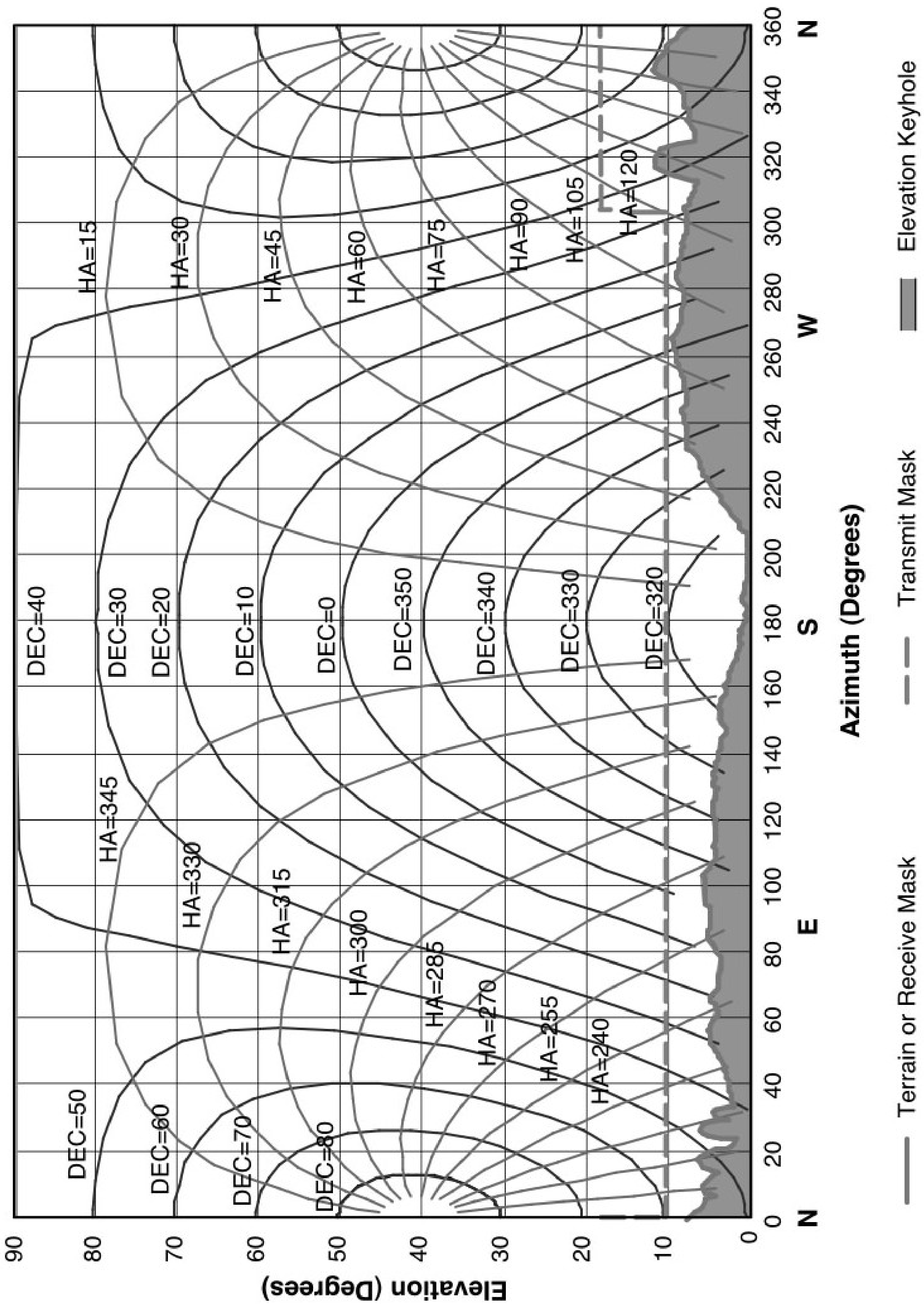

Figure 25. DSS 55 Hour-Angle and Declination Profiles and Horizon Mask

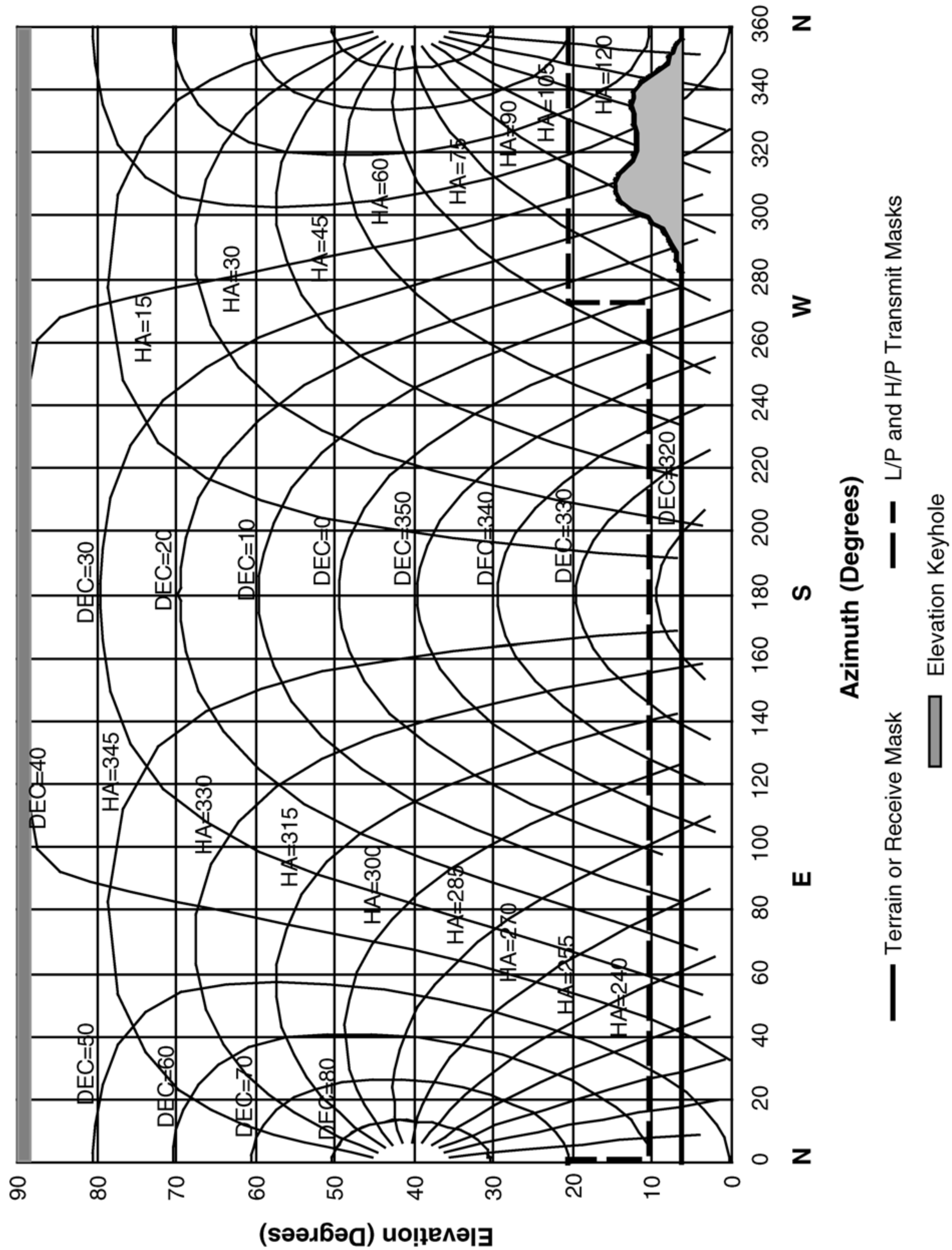

Figure 26. DSS 63 Hour-Angle and Declination Profiles and Horizon Mask

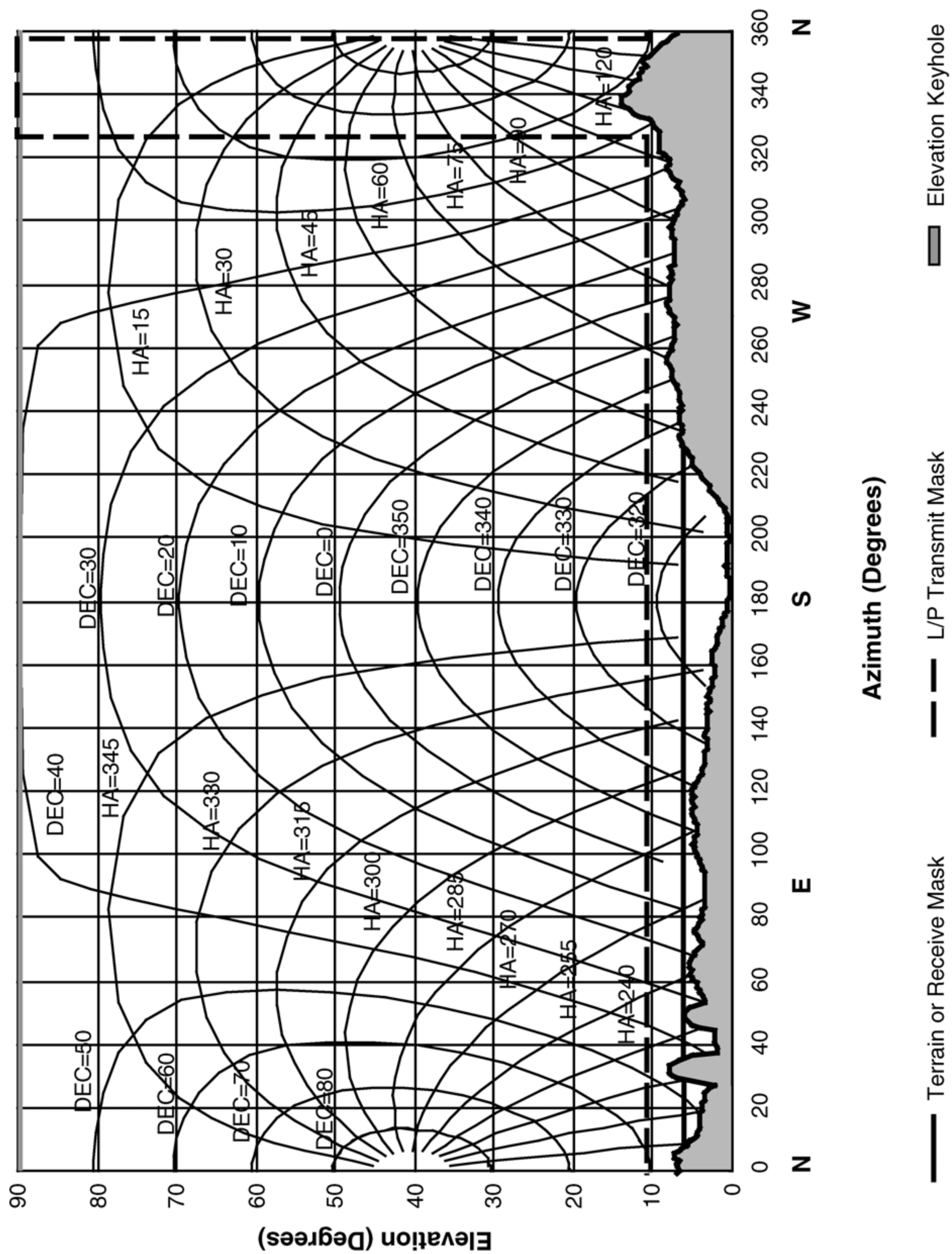

Figure 27. DSS 65 Hour-Angle and Declination Profiles and Horizon Mask

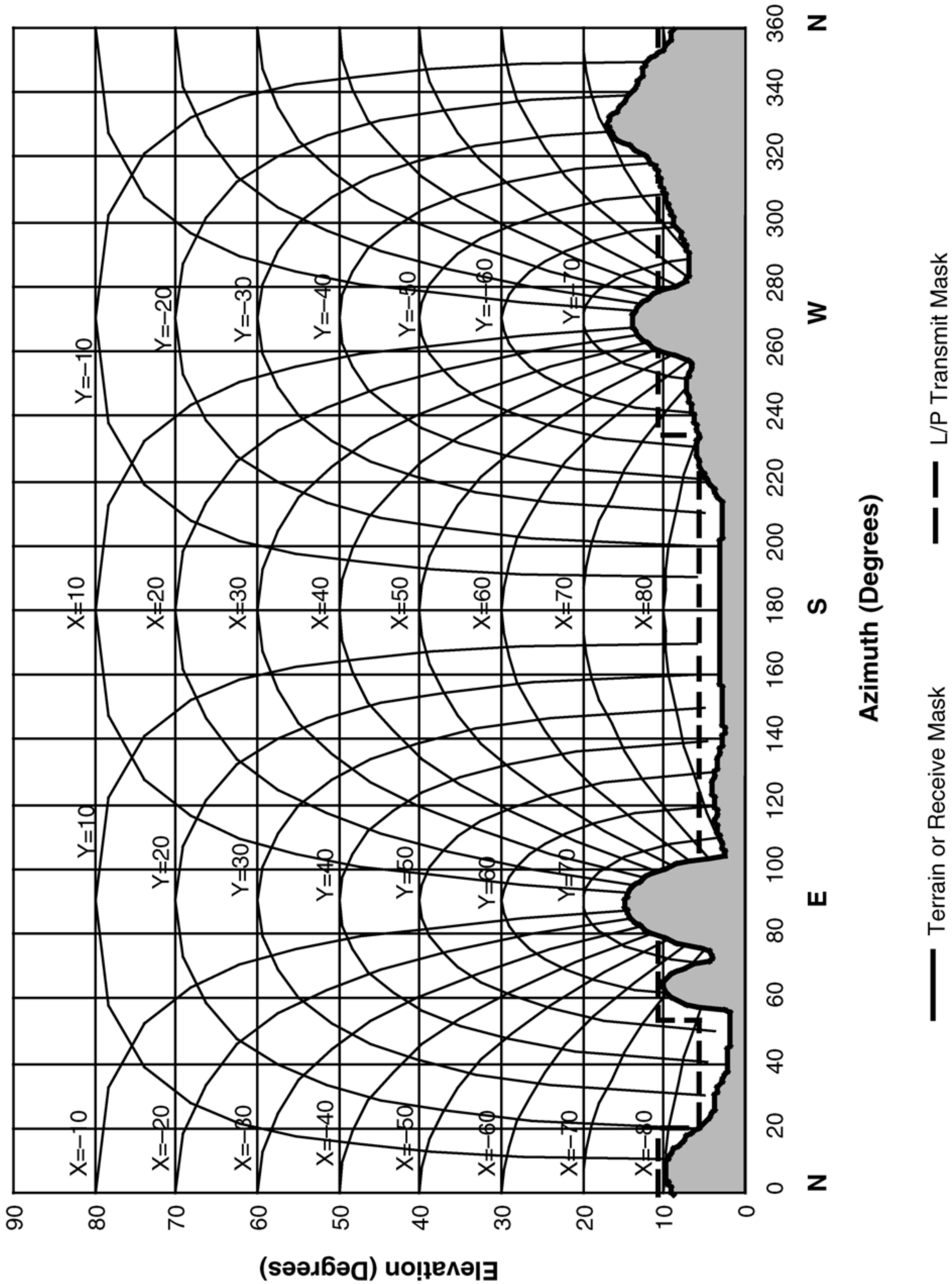

Figure 28.DSS 66 X-Y Profiles and Horizon Mask

Appendix A
References

1 C. Boucher, Z. Altamimi, and L. Duhem, *Results and analysis of the ITRF93*, IERS Technical Note 18, Observatoire de Paris, October 1994

2 B. R. Bowring, "The accuracy of geodetic latitude and height equations," *Survey Review*, 28, pp. 202-206, 1985.